

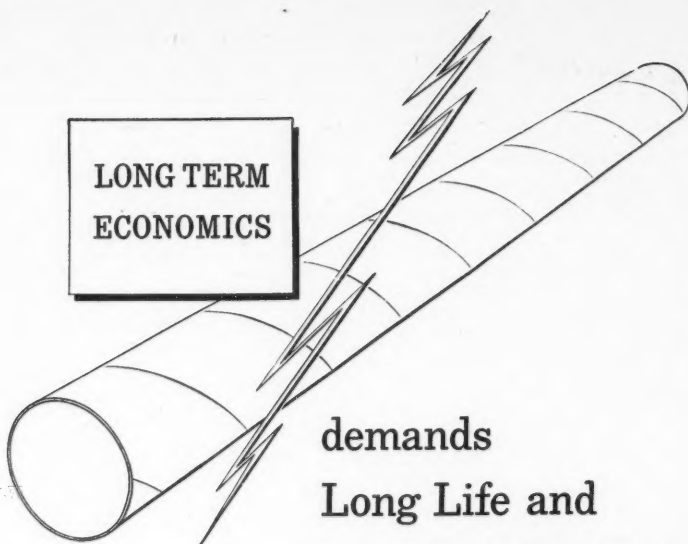
# Corrosion



Processing Corrosion-Resistant Steel—

Page 287  
TECHNOLOGY DEPT





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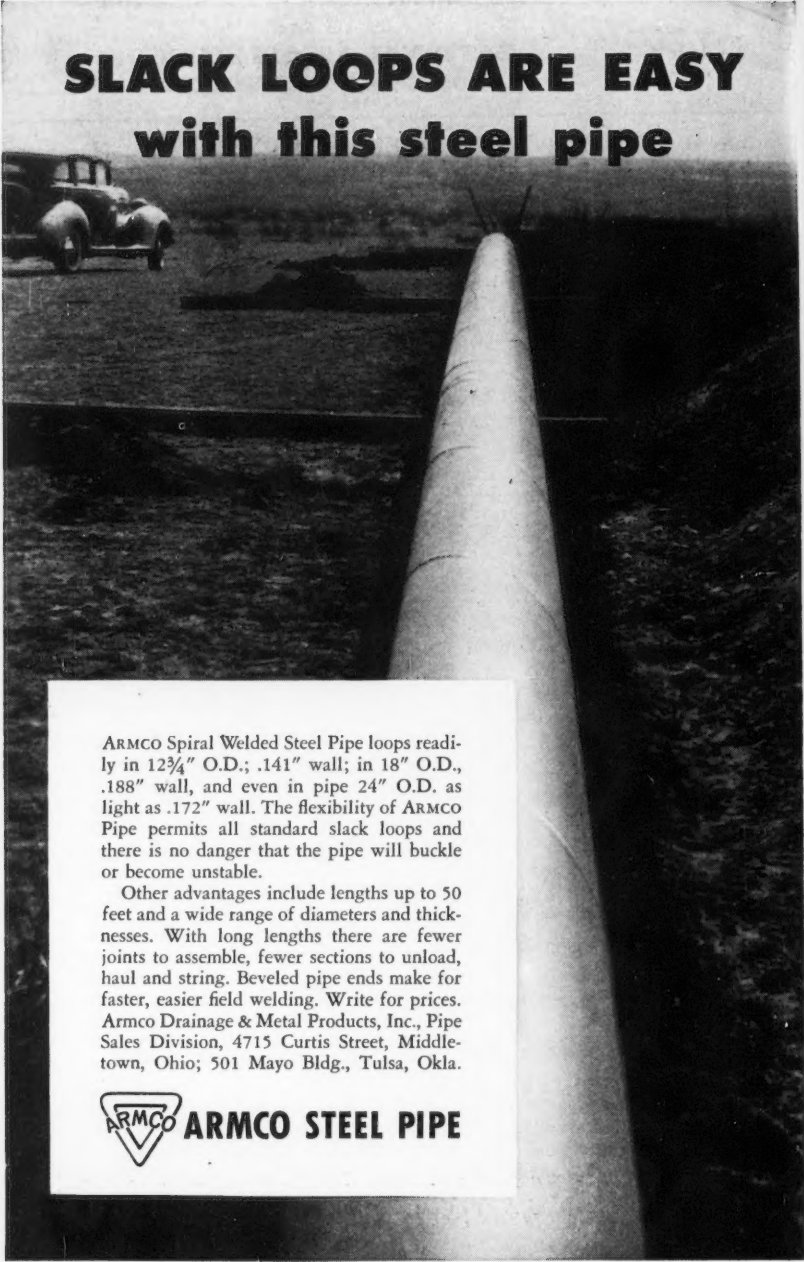
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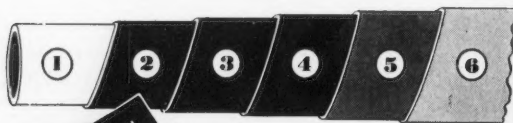
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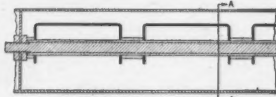
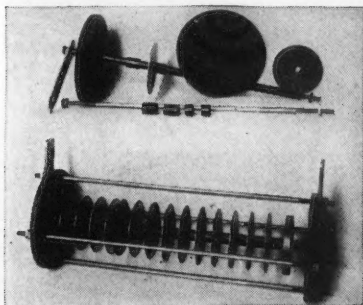
ardization of the specimens permits advance preparation of many specimens and holders, thus reducing the time required to get a test started.

Normally, the stock of specimens on hand at INCO amounts to a total of 10,000

where the spool-type holder cannot be used. Specially-designed holders are then provided. For example, for corrosion studies in pipe lines the device shown below has proved useful.

Other devices have been developed for still more specialized cases.

Today, in an average month, the INCO Corrosion Engineering Section sends out approximately 20 test spools. Normally, 40 to 50 spools are in use providing data for plants all over the



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The holder is of standard dimensions and construction. Specimens, too, are of standard shape and size. Stand-

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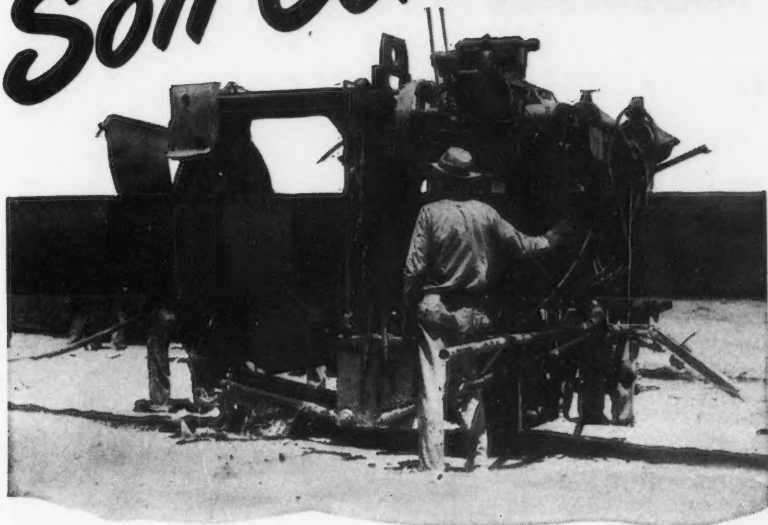
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*By*

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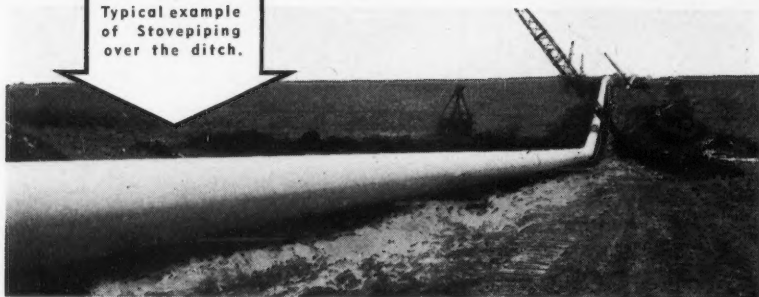
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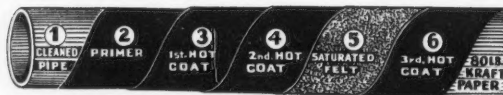
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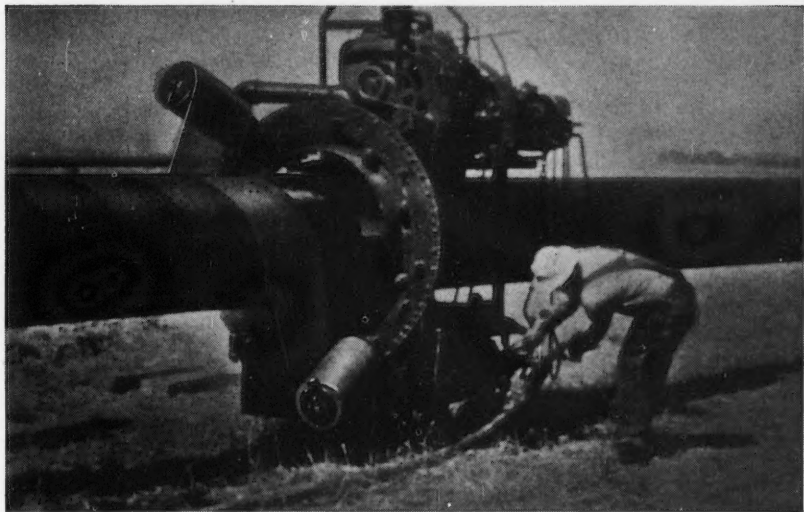


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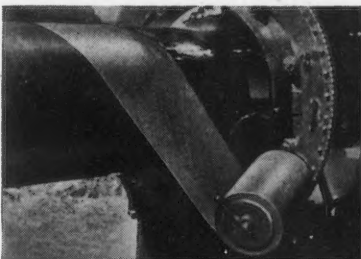
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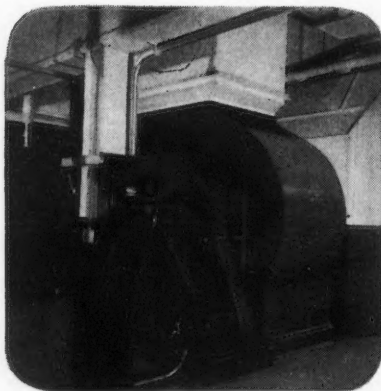
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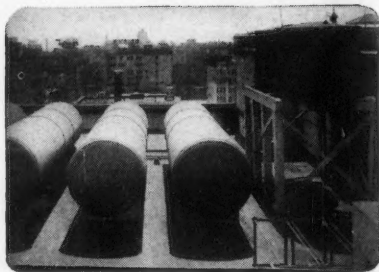
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# Corrosion-Resistant Processing Equipment of Clad Steels for Chemical and Allied Industries

By Everett C. Gosnell

Manager, Chemical Division, Lukens Steel Company, Coatesville, Penna.\*

**CLAD STEEL PLATE** is a bi-metal plate consisting of a light layer of corrosion-resistant metal bonded to a heavier layer of steel as a backing plate. Although clad steels have been commercially available since 1931 and have been proved in many applications, the war period with its shortage of critical materials brought about a more general acceptance of clad steels by the chemical and allied industries.

Clad steels were originally developed for the fabrication of large, corrosion-resistant equipment which if fabricated of solid corrosion-resistant metal, would be prohibitive in cost.

Clad steels may be divided into two main classifications:

1. Homogeneously bonded plate.
2. Non-homogeneously bonded plate.

The largest tonnage of clad steel commercially produced in this country is homogeneously bonded plate, produced by one of the following methods.

1. Bonding using heat and pressure; rolling on a plate mill at elevated temperature near the fusion point of the materials.

2. Deposition of the corrosion-resistant metal on a steel slab by electro methods using metallic rod or other means of controlling composi-

tion; followed by hot rolling to required thickness.

Non-homogeneously bonded clad plate consists of a thin covering or lining of the corrosion-resistant metal attached to a heavier steel plate by plug, spot, "stitch", or resistance welding, and in the practical sense, is not bonded all over the surface. An air space exists between the two layers which may be detrimental if heat transfer is a factor as such an air space would retard heat transfer. Clad plate of this type is not particularly desirable for fabrication of equipment for vacuum.

Homogeneously bonded clad steel plate is the most generally accepted clad material. The greater tonnage of bonded clad plate is produced by the heat-pressure or hot-rolling method.

The steps in the production of homogeneously bonded clad steel plate are as follows:

Figure 1 shows assembly of the halves of the "pack" or rolling assembly. Two clad steel plates are produced at the same rolling. The pack shown weighs approximately 45,000 pounds and will produce two finished plates  $219 \times 59\frac{3}{4} \times 3\frac{3}{8}$  inches of 10 percent nickel-clad steel. Contact with the rolls is made by the steel backing plate only, thus eliminating possibility of rolling iron, scale or foreign material into the surface of the corrosion-resistant material. Note that the corrosion

\* Now Manager, Chemical and Process Equipment Division, Colonial Iron Works Company, Cleveland, Ohio.



"inserts" do not come to the edges of the steel backing slab, steel "spacer bars" being used to fill this gap when assembling the halves of the "pack". The "inserts" are welded along the edges to the backing steel slab to prohibit shifting of position during handling and heating prior to rolling. The dimensions of the inserts and steel backing slabs are predetermined for the size of clad plates to be produced.

The halves of the "pack" are assembled by placing one on top of the other, with a parting material between the adjacent surfaces of the corrosion-resistant "inserts". The resultant "pack" then is welded on all four edges by automatic method. The "pack" then is heated in a "soaking pit" for the required time and temperature to assure even heating.

Figure 2 shows "pack" taken from "soaking pit" and ready for rolling.

Figure 3 shows rolling of the "pack" on a 206-inch mill, world's largest plate mill. Note that the rolls touch only the steel backing plate, thus eliminating possibility of rolling iron, scale, or foreign material into the surface of the corrosion-resistant material. This is emphasized for it is very important. Bonding between the steel and corrosion-resistant "inserts" results from the hot rolling at temperatures approaching the fusion point of the materials. After rolling for length, width and gauge, with cross rolling to refine structure of the metals, the composite two-plate "sandwich" is allowed to cool.

Figure 4 shows flame-cutting on all four sides, inside the weld, to remove area resulting from spacer bar, and to permit separation of two plates as shown in Figure 5. Note flame-cutting of clad steel plate is

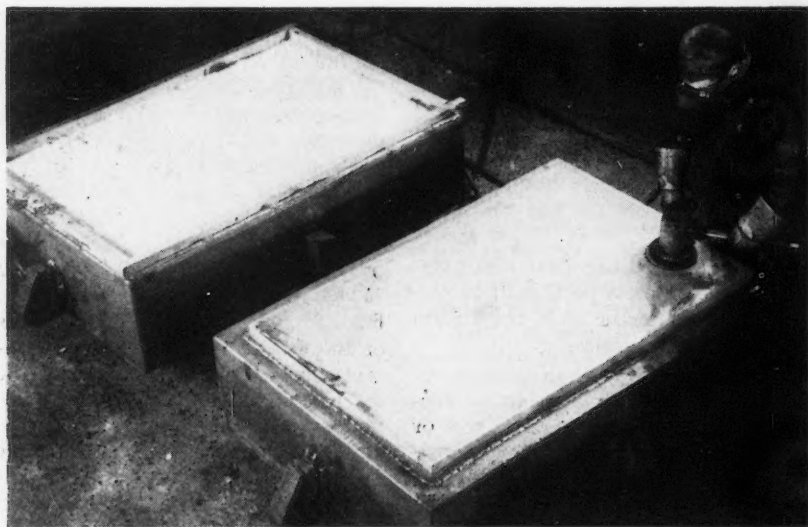


Figure 1—Halves of clad pack shown ready for final assembly.





Figure 2—Clad pack from soaking pit ready for rolling.

done from steel side. Light gauges of clad plate are sheared while heavier gauges are flame-cut. After cleaning to remove parting material, the final pattern is laid out, as shown in Figure 6, for shearing or flame-cutting. The finished clad plates are given final inspection as shown in Figure 7.

The following clad steels are commercially available in plate and heads: nickel, Monel, Inconel, stainless, (all commercially available compositions of 18 percent chromium, 8 percent nickel austenitic series), straight chrome steels and silver. In the past, copper, Everdur, and 70-30 cupro-nickel clad steels were produced, but at present are not commercially available. Experimental work has been in prog-

ress for some time on Hastelloy "B" clad steel; however, this work is not completed and, this clad material is at present not commercially available.

#### Desirability of Corrosion-Resistant Processing Equipment

Corrosion-resistant processing equipment may be desirable for the following reasons:

1. To prolong life of equipment.
2. To protect quality of products.
3. To reduce maintenance costs.
4. To stop unnecessary loss of production through elimination of excessive "shut downs" for repairs.
5. To permit ease of cleaning or sterilization.
6. To reduce equipment cost per unit of product produced.

Possibly the most important factors mentioned are protection of quality of product and more continuous production through elimination of unnecessary "shut downs" for repairs.

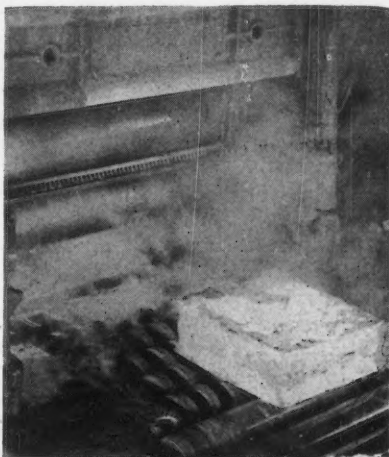


Figure 3—Rolling clad pack. Bonding is produced in this operation.



The availability of corrosion-resistant equipment has also made possible some processes which could not be conducted in equipment of ordinary materials. For example, metallic contamination may act catalytically and thus make it impossible to control reactions.

### Selection of Corrosion-Resistant Metal

Assuming that corrosive conditions are present, the first problem is that of selection of the best and most economical metal. The following factors affect the corrosion rate of metals:

1. Nature and concentration of corrosive media.
2. Temperature.
3. Degree of aeration.
4. Rate of flow or movement.
5. Presence of impurities.

Considerable corrosion data are available in books and technical publications. A large amount of corrosion data from tests in laboratories and under plant conditions are available from manufacturers of metals and alloys. Service records are sometimes available on equipment for the same or similar conditions, and are good guides in selection of materials.

The most reliable corrosion information is obtained from corrosion tests conducted in plant production equipment under conditions of actual service.

Proper selection of material is possibly the most important single factor in the design and fabrication of processing equipment. There is no metal or alloy which is a "cure all" for all corrosion problems, each material having its range of usefulness.

In many cases, the most effective corrosion-resistant material is not the most economical material. Having available reliable corrosion rates, it is possible to select the most economical material and design the equipment of clad steel for the required life or to obsolescence.

An example is shown in Figure 8—a 1,200-gallon extractor for glandular products, fabricated of 15 percent Inconel-clad steel plate, 5/16-

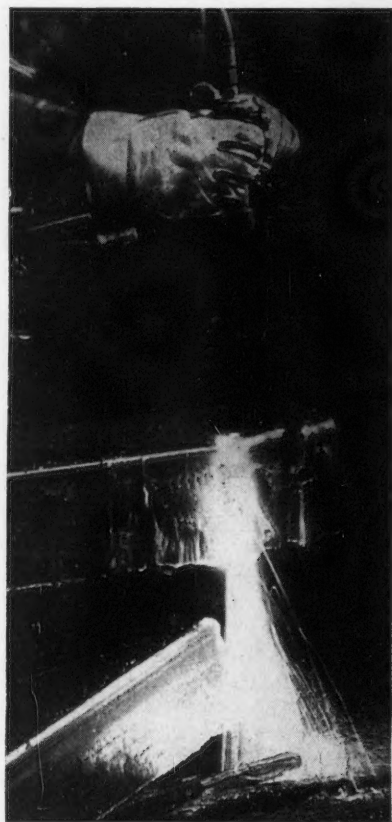


Figure 4—Flame-cutting prior to separation into two plates. Note the parting line.



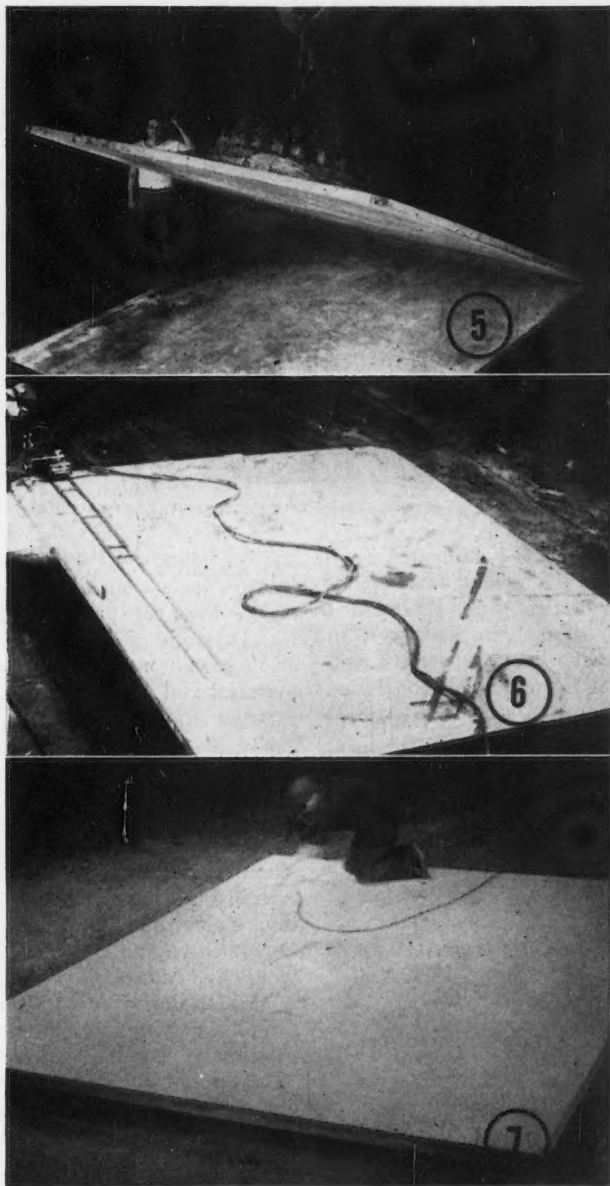
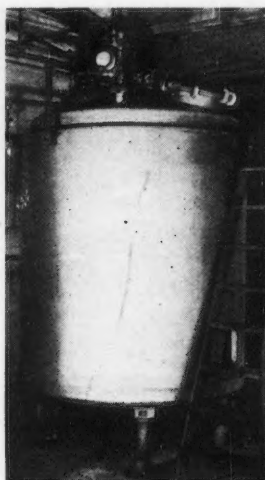


Figure 5—Separating pack into two clad steel plates.  
 Figure 6—Final pattern layout of clad plate, ready for flame-cutting.  
 Figure 7—Final inspection of clad plate prior to shipment.



inch in thickness, five feet eight inches in diameter and eight feet in depth. The representative corrosion data indicated a corrosion rate of 0.0002 inches penetration per year in this application. At this rate, the indicated life of this equipment would be 234 years, but why worry about more than 100 years, and why use equipment of more expensive solid corrosion-resistant materials? A re-

circulating tank of Inconel-clad steel, still of Inconel for recovery of solvent, and also pipe, valves and fittings of Inconel are used in conjunction with this extractor. There are at least three such Inconel-clad extractors now in service.



*Corrosion Rates  
Based on Continuous Exposure*

<i>Average Corrosion Penetration Per Year in Inches</i>	
<i>Metal</i>	
Inconel	0.0002"
Nickel	0.0111"
Monel	0.0033"
Mild Steel	0.0612"
Cast Iron	0.0500"

Figure 8—Jacketed extractor for pharmaceutical product.

### Design of Equipment

After selection of proper material, comes the problem of design. Good design of equipment may be as important as proper selection of material and good fabrication.

Some equipment may be produced easily by casting. Most plant processing equipment, however, lends itself more readily to fabrication by welding of wrought materials, plate or sheet. The greater volume of chemical equipment is produced by welding fabrication, utilizing metallic arc electrodes for butt type welding. It is desirable to eliminate fillet welds and lap joints where possible. It is also desirable to eliminate all possible galvanic action from use of dissimilar metals. Accessory parts, valves, pipe, etc., should be of the same corrosion-resistant material as the equipment, if possible, otherwise the Electromotive Series should be used in selection of materials for accessory parts, using metals near

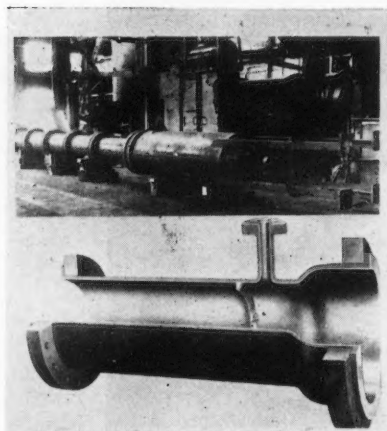


Figure 9—Continuity of corrosion-resistant surface. Reboiler for hydrofluoric acid.



each other and thus preventing serious galvanic corrosion.

The effect of galvanic contact of metals on their individual corrosion rates is shown by the results of the following test in 30 percent formaldehyde for 45 days.

Metal	Inches Penetration Per Year.
Monel	0.0009
Nickel	0.0003
Inconel	0.00001
Stainless Steel	0.00001
Aluminum 2S	0.0036
Monel	0.00003
Aluminum 2S } galv. couple	0.0067
Nickel } galv. couple	0.00003
Aluminum 2S } galv. couple	0.0067
Inconel } galv. couple	0.00001
Aluminum 2S } galv. couple	0.0067
Stainless Steel } galv. couple	0.00001
Aluminum 2S } galv. couple	0.0067

**NOTE**—Aluminum 2S samples in this test were discs 0.031-inch thick, and all were perforated in several places during the test.

You will note that the corrosion rate of aluminum 2S was practically doubled when in galvanic contact with the other metals and alloys.

Stray currents also may affect corrosion greatly, particularly if dissimilar metals are present. All electrical equipment should be well grounded with a separate ground not in any way connected to other metal equipment.

Continuity of corrosion-resistant surface is an important factor in design of equipment as illustrated in Figure 9, a silver-clad steel reboiler and tower, and artists cut-away drawing of one section. These towers were fabricated of 10 per cent and 15 per cent silver-clad steel,  $\frac{3}{8}$  and  $\frac{7}{8}$ -inch in thickness, handling hydrofluoric acid.

Heads of clad steels as well as solid corrosion-resistant metals are commercially available in many types and in a wide range of sizes

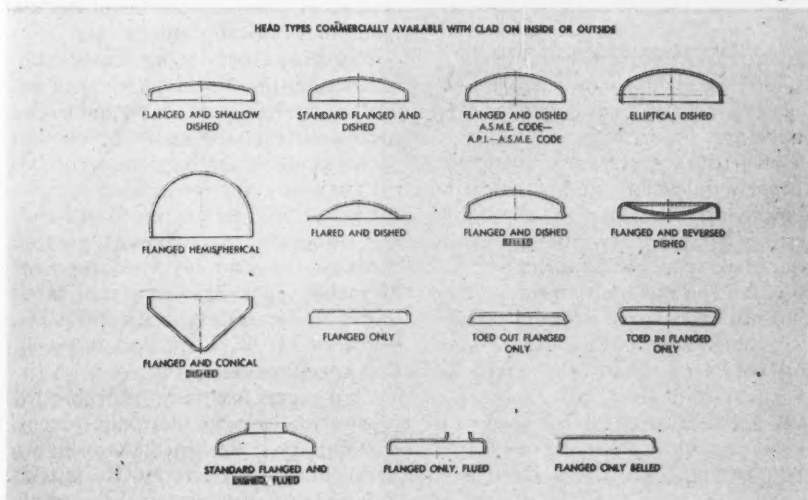


Figure 10—Commercially available types of clad heads.



to over 18 feet in diameter. Head types are shown in Figure 10. Use of heads with flanged section, in preference to flat plate or sections made by welding several plates, facilitates design and fabrication using butt welding.

Flued openings are available in heads, and should be incorporated in design for connections and when sections of equipment are to be joined with flanges. Figure 11 shows a flued opening in a nickel-clad steel elliptical head, 66-inches inside diameter, 3-23/32 inches thick.

The use of wide plates of clad steels reduces the number of welds and their attendant operations, effecting considerable saving in fabrication cost and man hours and also simplifies design. Clad steel plates are available up to 162 inches in width or 480 inches in length, although these limits are not available in all gauges. The large nickel-clad plate, shown in Figure 12, is 151x152x3/4 inches.

### **Fabrication of Equipment**

Good fabrication of corrosion-resistant processing equipment is very important. Fabricators should be selected with care, choosing those with proper equipment and fabricating experience. The size of the fabricating company is not always a guarantee of a good fabricating job on corrosion-resistant equipment, as in some cases past experience may have been with equipment of steel and cast iron. With the exception of silver-clad steel, all clad materials are fabricated by relatively the same procedure. Atomic hydrogen and acetylene welding have been used successfully with silver-clad steel.

In general, for the fabrication of processing equipment of clad steels, butt type welding, with proper metallic arc electrodes is recommended.

Fitting of plate to be welded is very important. Plates should be fitted as closely as possible, providing an even clad surface. Desirable and undesirable types of weld joints are shown in Figure 13.

Sequence for butt welding is shown in Figure 14. Clad plates are beveled from the steel side leaving a steel "land" of approximately 1/32-inch below the clad interface. After careful fitting, the plates are tack welded from the steel side. Normal procedure is then to complete the welding of the steel side with steel electrode. Flux is then removed from the junction area on the clad side with a small round-nosed tool. The corrosion-resistant weld is then made with the proper electrode, preferably in two or more passes.

The corrosion resistant surface of clad steel plate should be protected from mechanical damage and iron contamination during fabrication. Bending rolls should be cleaned or, preferably, heavy paper pasted to the corrosion-resistant surface of clad plates prior to rolling into cylindrical shells.

Care should be exercised in bending on brake, to prevent cutting through the clad layer. Equipment of many types has been fabricated under boiler code specifications using U-68, U-69, U-70 and unclassified specifications.

Clad steels are very desirable for fabrication of large plant equipment, particularly if designed for pressure or vacuum, which requires appreciable thickness of material for physical reasons.



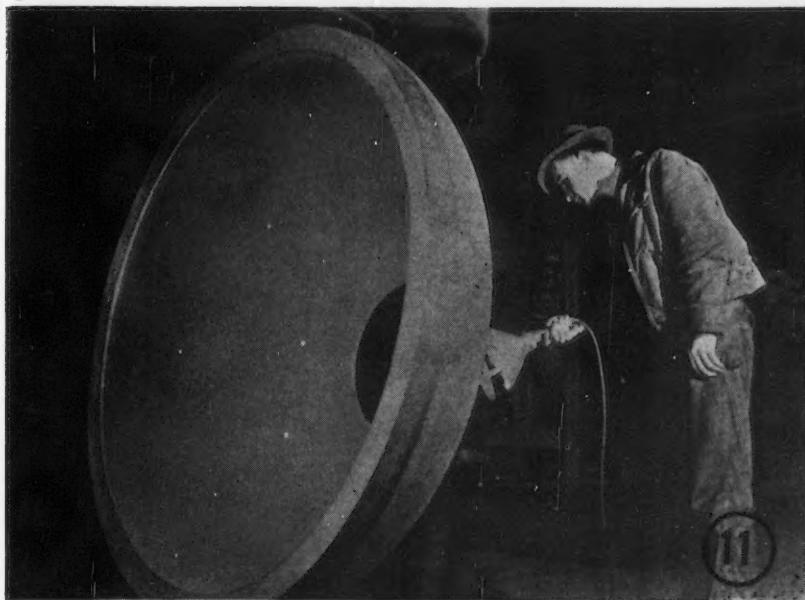
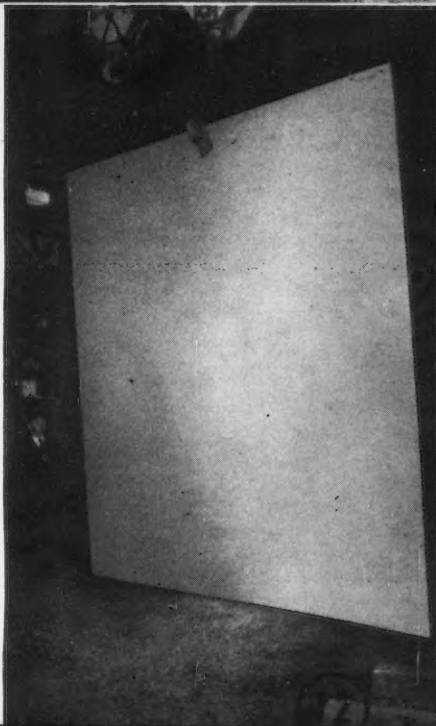


Figure 11—Elliptical head, with large flued opening.

Figure 12—Large plate of clad steel.

Processing equipment of many types is in service in many applications in a large number of industries. A complete discussion of all types and applications would be too extensive for presentation in this paper. Accordingly, representative types of equipment have been selected, classified by industrial field and presented in illustrations.

Figure 15, shows a Zaremba triple effect, multi-circulation evaporator for caustic soda, with 7-foot, 6-inch diameter and 14-foot cylindrical section and conical bottom; fabricated of 5/16-inch and 3/8-inch thick





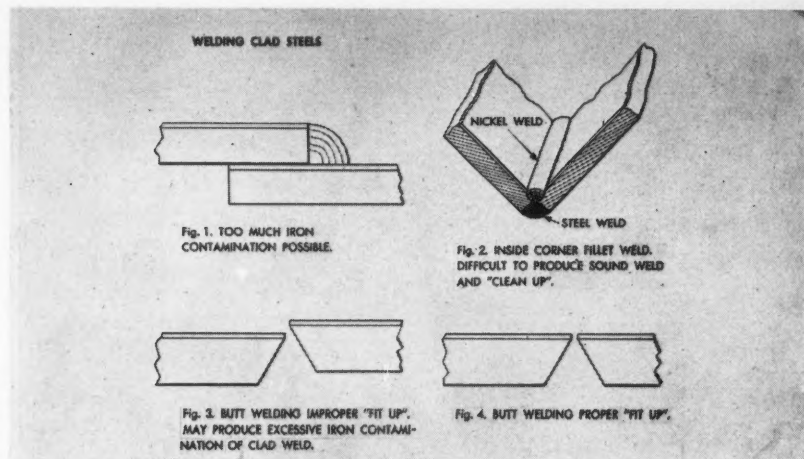


Figure 13—Desirable and undesirable types of clad welds.

nickel-clad steel. Salt separators six-feet in diameter, and vacuum flash tanks, five feet in diameter also fabricated of nickel-clad steel are used in conjunction with this evaporator. Single and double effect evaporators of nickel-clad steel are

also in service handling caustic soda. Similar evaporators are in service handling sodium and barium sulfide.

There are many other applications of nickel-clad steel for equipment for handling, transporting and manufacturing of caustic. The first commercial application for nickel-clad steel was the fabrication of tank cars for the transportation of caustic soda to eliminate contamination of the product. Figure 16 shows one of five 10,000-gallon, all-welded tank cars of nickel-clad steel fabricated by American Car and Foundry Company, Milton, Pennsylvania. The tank is 7 feet,  $2\frac{1}{4}$  inches in diameter by 32 feet in length. The first nickel-clad cars were either riveted or lap welded, with butt straps. Latest cars are butt welded using automatic welding of steel backing plate. Nickel-clad steel tank cars also have been used successfully for transportation of phenol, special organic chemicals, neutral spirits and gin.

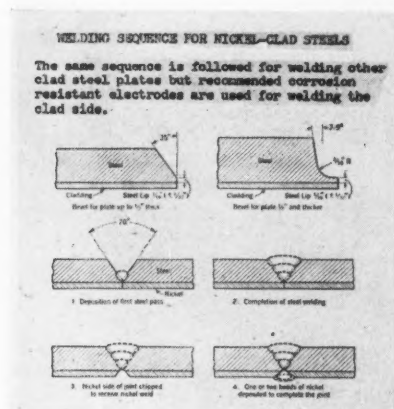


Figure 14—Welding sequence of clad steel for butt welding.



In Figure 17, a cross section of a heating tube, five inches in diameter, is shown. This tube was fabricated of 40 percent "L" nickel-clad steel ("L" nickel is a special low carbon

grade) and used in fused caustic equipment. The "L" nickel layer of the exterior of this tube provides adequate resistance to attack of fused caustic, the steel inner surface being in contact with gases of combustion of oil or gas which may be fairly high in sulfur content. "L" nickel is very desirable for resistance to fused caustic or fused nitrites, the latter as used in metal heat treatment.

Other applications involving caustic for which nickel-clad steel equipment is in service are dissolving, storage, neutralizing and settling tanks; filter parts; and equipment for production of flake caustic.

A large tonnage of nickel-clad and Monel-clad steels has been used for fabrication of equipment for production and handling of salt. Figure 18 shows a large rotary salt drier, six feet in diameter and 40 feet long, fabricated of 3/16 and 3/8-inch thick 20 percent Monel-clad steel. Driers of this type, fabricated of one-third Monel-clad steel (wet end) with the balance of nickel-clad steel, give excellent service. Older salt driers were

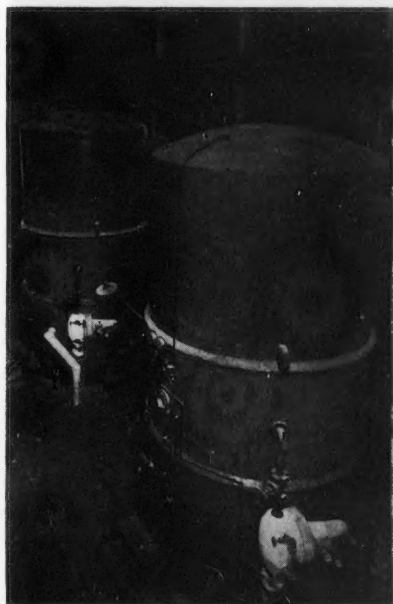


Figure 15—Triple effect, multi-circulation evaporator for caustic soda.

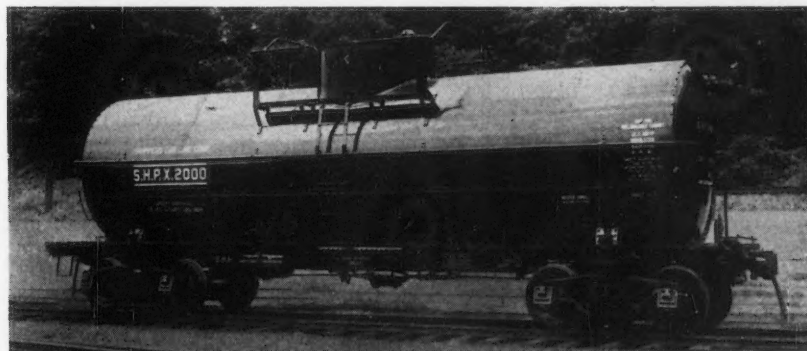


Figure 16—All-welded clad steel tank car for transportation of caustic soda.



fabricated entirely of nickel-clad steel. Driers of this type are also used for other chemicals.

Other equipment of nickel-clad steel for the production and handling of salt include dissolving, settling, circulation and storage tanks; grainers, conveyors, centrifugal housings, mixers, evaporator pans and filters.

Figure 19 shows three large chemical reactors fabricated of 20 percent nickel-clad steel. A saving of 30,000 pounds of nickel was effected by fabricating this equipment of clad steel instead of solid nickel.

Mixers of many types have been made of clad-steel plate. The one shown in Figure 20 is a standard design, fabricated of 10 percent and 20 percent, 3/16 and 13/32-inch thick nickel-clad steel and used in production of dye stuffs and intermediates.

Clad steels have been used extensively for shells as well as for tube sheets of condensers, coolers and heat exchangers. Care must be exercised in rolling tubes into clad tube sheets. The vacuum condenser shown in Figure 21 has 10 percent and 20 percent nickel-clad steel plates for shell and tube sheet. This condenser is used in chemical processing and is 35 inches in diameter and 11 feet, 4½ inches in length.

#### Pharmaceutical, Fine Chemicals and Proprietary Products

Large sterilizers and disinfectors, as shown in Figure 22, are used in production of biological materials such as penicillin, and in hospitals for sterilization and disinfection of instruments, utensils, bandages, operating room supplies and bedding.

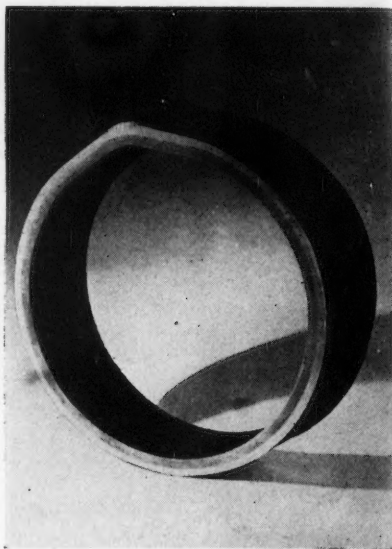


Figure 17—Section of outside-clad steel tube used in caustic fusion equipment.

In the fabrication of the jacketed unit shown, a plate of 10 percent nickel-clad steel 7/16-inch thick was used for the inner shell, which is 10 feet x 30 inches x 6 feet. The inner shell is subjected to corrosive action of saline and disinfecting solutions in presence of steam.

Glandular extractors made of Inconel-clad steel have been previously mentioned and illustrated in this article. Other clad steel applications in pharmaceutical manufacturing include: driers for effervescent salts; processing tanks and kettles for production of vitamins and extracts of meat, liver and fish oils; bleaching and storage tanks for glycerine; processing tanks for milk of magnesia; evaporators and processing tanks for gelatin; evaporators for tonics; storage tanks and recovery equipment for phenol; mixers and



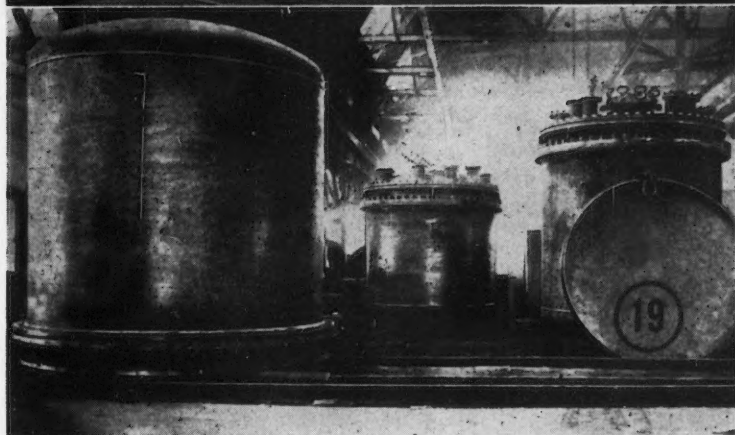
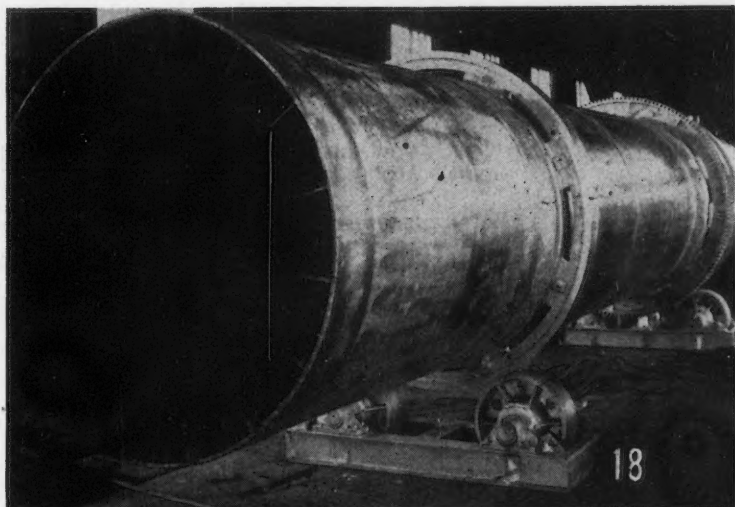


Figure 18—Rotary salt drier.

Figure 19—Group of three chemical reaction tanks.



processing kettles for cosmetics and proprietary products; working surfaces and table tops of clad steels.

### Food—Processing and Packing

Figure 23 shows a nickel-clad tank 10 feet in diameter x 54 inches on straight side, with cone bottom, fabricated of  $\frac{3}{8}$ -inch thick 10 percent nickel-clad steel. This equipment is used in production of infant food, containing milk powder and malt products.

Figure 24 is a shop view during fabrication of an evaporator of  $\frac{1}{2}$ -inch thick, 20 percent Inconel-clad steel. This long tube, vertical evaporator is used for production of pectin.

Other applications of clad steels in this field include working surfaces and table tops for handling meats and dairy products; dissolving and storage tanks for brines and sugar solutions; glucose evaporators, crystallizers, cooling and storage tanks; cooling kettles for candy manufacture; evaporators and processing tanks for gelatin; blending tanks

for creamed corn; processing kettles for extracts, flavors and fountain syrups; vegetable cutters and mixers; quick-freezing equipment for fruits, vegetables, meats and fish.

### Petroleum Industry

Equipment for the petroleum industry is mainly of large dimensions and designed for pressure; thus clad materials are ideally suited for its fabrication.

Figure 25 shows a batch still 9 feet in diameter x 21 feet in length fabricated of  $\frac{3}{8}$ ,  $\frac{1}{2}$  and  $\frac{5}{8}$ -inch thick, 20 percent nickel-clad steel. Equipment of this type has also been fabricated of Monel and stainless-clad steels, the choice of materials depending upon service conditions.

Other applications for clad steels in petroleum equipment include towers; catalytic separators and traps, coagulators, settlers, caustic treating tanks, and revivifiers; cracking vessels; chlorinators; grease kettles; large diameter pipe, for sludge and "run down" lines; and condenser and heat exchanger tube sheets and

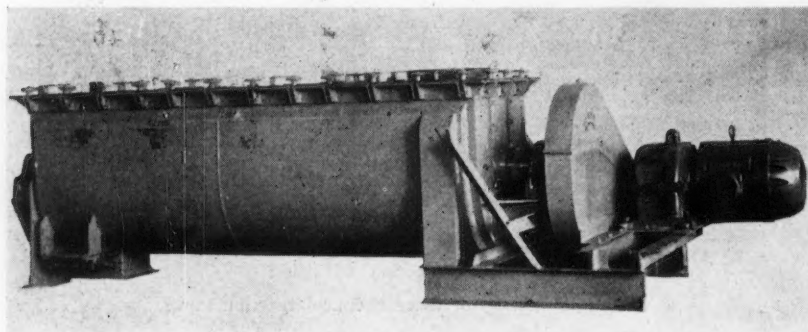


Figure 20—Mixer for dye stuffs.



shells. Reboilers for hydrofluoric acid of silver-clad steel have previously been illustrated.

### Pulp and Paper Industry

The pulp and paper industry started on an extensive program of modernization of plant equipment which was retarded during the war. Equipment of steel, cast iron, copper and brass was previously used. There are many applications for which clad steels are very desirable to prolong life of equipment, to reduce maintenance cost, and to insure continuous production of high quality products.

Many pulp producing plants operate electrolytic chlorine units and nickel-clad steel has been extensively used for evaporators, tanks, heat exchangers and preheaters

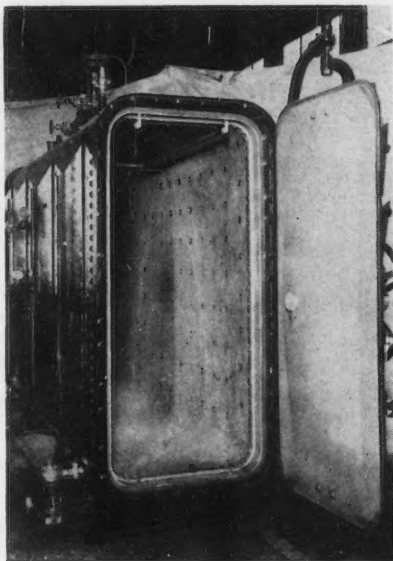


Figure 22—Hospital sterilizer and disinfectant.

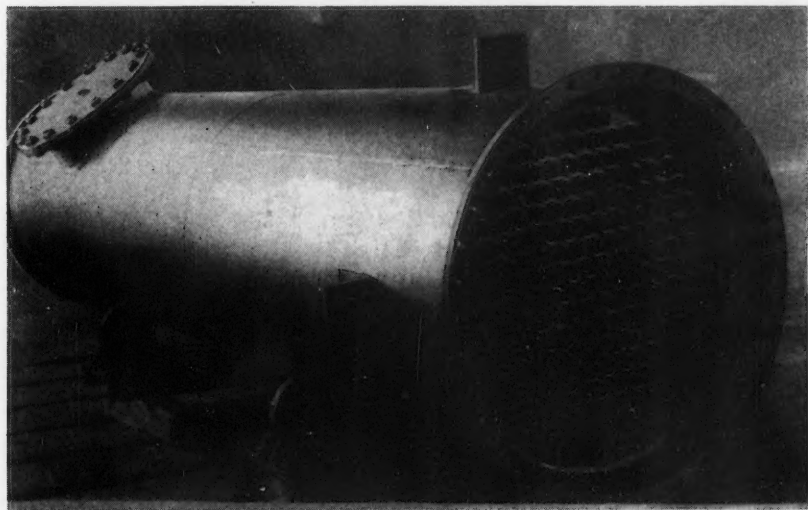


Figure 21—Vacuum condenser for chemical production.



Figure 23—Conical bottom tank for handling milk powder and malt products.

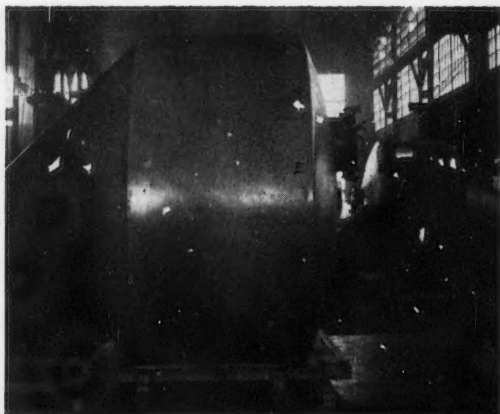


Figure 24—Vertical evaporator for pectin production.

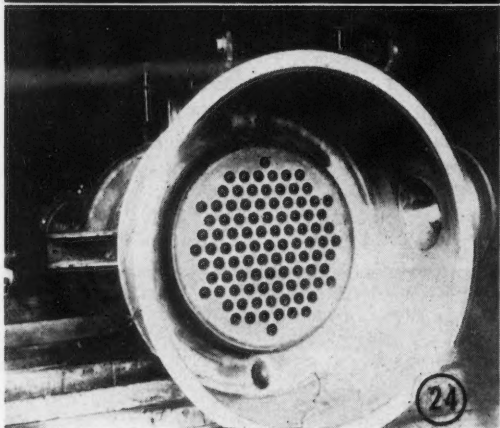
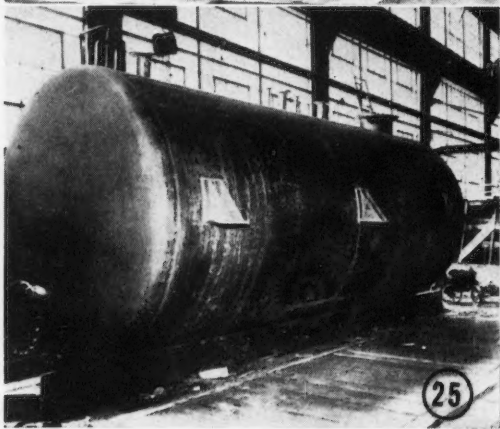


Figure 25—Oil batch still for petroleum.





handling caustic, in connection with such equipment.

Flow and head boxes of nickel and stainless-clad steels have been in service for years and are now standard in many plants.

Figure 26 shows the first complete cylinder mold vat with nickel steel center section, 11x8x4 feet in size.

"Hydrapulpers" for production of white pulp for the paper machines, have recently been redesigned from cast iron and are now fabricated mainly of nickel-clad steel. This equipment consists of a large open top cylindrical tank, six to 20 feet in diameter, with a cone or dished head at the bottom. A large revolving beater head is located in the bottom of the tank. Stainless-

clad steel also has been used for such equipment.

Figure 27 shows an experimental rotary digester, six feet in diameter, built to conform to Par. U-69 of ASME code, for a working pressure of 200 psi and tested at 400 psi. This digester was fabricated of 9/16-inch thick, 10 percent nickel-clad steel. It is used for production of wood fibre for insulating board. Large plant installations of equipment of this type were retarded by the war.

Other applications for clad steels in the pulp and paper industry are digesters, diffusers, black liquor evaporators, storage tanks, and black ash leaching tanks in the soda and sulfate processes. Equipment for

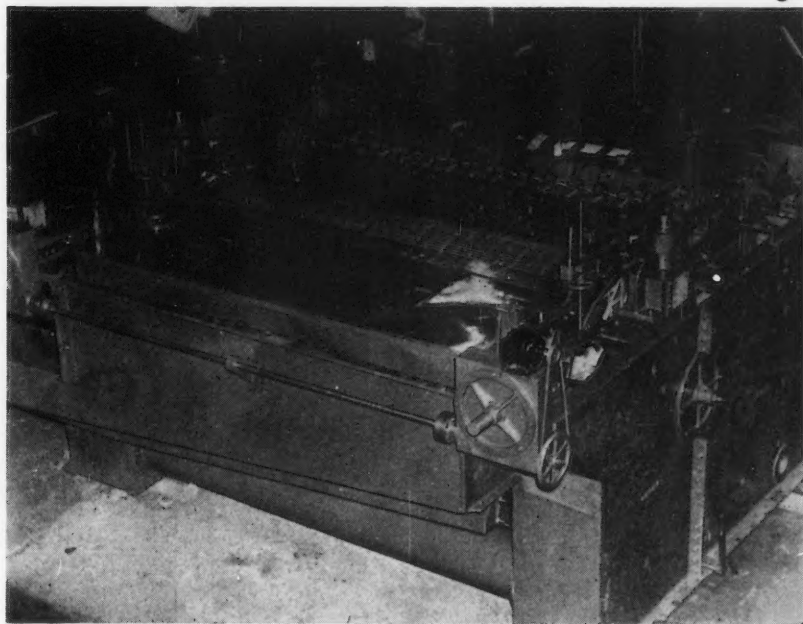
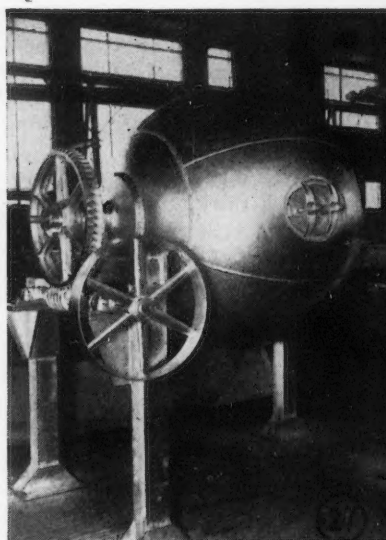


Figure 26—Cylinder mold vat for paper manufacture.





handling and distillation of crude fatty acids and "Tall Oil" can be satisfactorily fabricated of Inconel-clad and Type 316 stainless-clad steels.

#### Soap, Fatty Acid and Cosmetics Industry

Figure 28 shows a soap boiling kettle, 11 feet in diameter and 21 feet, two inches in depth, fabricated of 3/16, 1/4 and 5/16-inch thick, 10 percent nickel-clad steel. The main corrosion attack occurs on the upper third of such kettles, at and above liquid level. Several old steel kettles have been reconditioned by cutting off the top third and replacing with nickel-clad steel. Nickel-clad is superior to stainless-clad steel for this application because of the presence of caustic and salt.

Other applications for clad

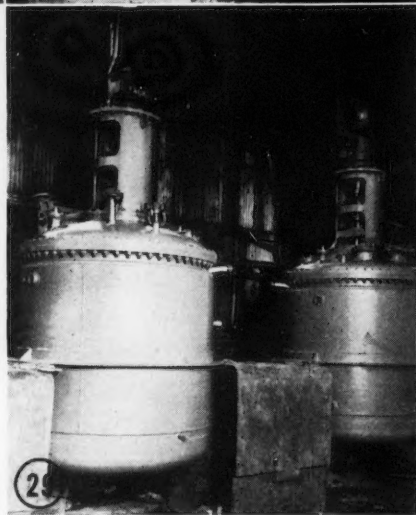


Figure 27—Rotary digester for wood fibre production.

Figure 28—Soap boiling kettle.

Figure 29—Resin reactors, 600-gallon capacity.



steels in this field include glycerine evaporators and bleach tanks, lye-salt hoppers and chutes, soap amalgamators and pladders, and processing kettles for cosmetics. Both Inconel-clad and Type 316 stainless-clad steels have been used for fabrication of fatty acid distillation equipment and autoclaves handling fatty acids. Inconel-clad is superior to nickel-clad steel for fatty acids at, or above, distillation temperatures, although nickel-clad steel is satisfactory for lower temperature operation.

Synthetic detergents, substitution products of fatty alcohols, are coming into wide use. One large producer of such products has standardized on Inconel and Inconel-clad steel for required plant production equipment, several new plants now being in process of construction. Some stainless-steel equipment is in serv-

ice at another producer of similar products.

Nickel-clad steel is an excellent choice for fabrication of large spray drying towers for production of soap powders.

#### Plastics, Resins, Varnish and Oil

Reactors of type shown in Figure 29 are extensively used by producers of resins and plastics. These jacketed, all-welded reactors of 600-gallon capacity, 54 inches inside diameter, and more than six feet in depth are fabricated of 20 percent nickel-clad steel and used for production of synthetic resins. Similar reactors of Inconel-clad steel and stainless-clad steels are also in service, the choice of material depending on type of resin produced, catalyst used and service conditions. Jacketed reactors are heated with steam or Dowtherm, some reactors being designed with-

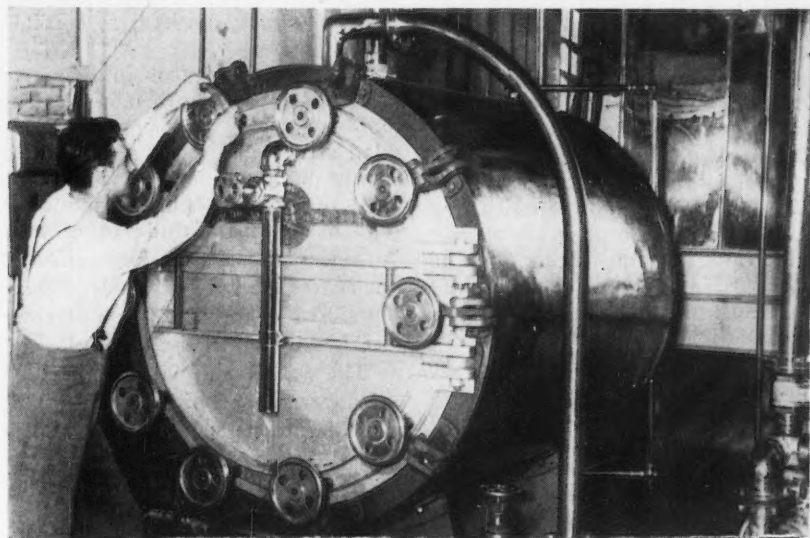


Figure 30—Horizontal hop strainer for brewery.



out jackets and heated with electric strip heaters.

Nickel-clad and stainless-clad steels have been used for the fabrication of underfired portable and set types of varnish kettles, varying in capacity from 150 to 2,000 gallons. Existing varnish kettles of copper, Monel and stainless steel have been reconditioned with replacement bottoms of nickel-clad steel and have thus provided years of additional life.

During the war, there was a great shortage of Tung, or China Wood, oil. Substitute oils were developed from castor and other vegetable oils produced in this country. Processing equipment of Inconel-clad steel has given excellent service in the production of such oils. Nickel-clad and Inconel-clad oil bodying kettles are giving good service.

Kettles and cooling trays of nickel-clad steel are giving excellent service in production of Ester gum and modified natural gums.

Phenol is used extensively in production of plastics and synthetic resins. Storage tanks of nickel-clad steel are used widely in this country for phenol storage, and are usually of 12,000 to 15,000-gallon capacity. Contamination of the phenol with metallic salts not only darkens the finished resin, but also may act catalytically and thus make the reaction difficult to control. Formaldehyde, also extensively used in resin manufacture, can be stored successfully in Inconel-clad equipment.

Nickel-clad steel has been used for years in equipment for production of plasticizers used in lacquer manufacture, particularly of the organic phosphate type.

Inconel-clad steel rosin melting and filtering equipment has been in service for several years.

Selection of materials for the fabrication of equipment for the production, handling and transportation of alcoholic beverages is a serious problem. Contamination of such products with extremely small amounts of metallic salts affects color, flavor and quality. Wines, particularly carbonated ones, are very susceptible to off-flavor by metallic contamination. Inconel-clad blending and bulk-fermentation tanks have given excellent service for years in production of champagne by the American, or bulk fermentation, process, producing a high quality product.

Nickel-clad tank cars give excellent service in transportation of neutral spirits and gin.

Mixing, blending, bottling and holding tanks of Inconel-clad steel are excellent for all types of distilled liquors, wines, cocktails, cordials and liqueurs.

Mash tubs, 18 feet in diameter and six feet in depth fabricated of 5/16-inch thick, 15 percent nickel-clad steel, have given good service in one distilling plant.

In the brewing field, storage tanks and mash tubs, Boudelot coolers, strainers and hop jacks of nickel-clad steel are very desirable. Figure 30 shows a horizontal hop strainer fabricated of nickel-clad steel.

The war period, with its shortage of corrosion-resistant materials, brought about a greater acceptance of clad steels by industry and was instrumental in developing many new applications for clad steels in processing equipment.



## Attenuation of Forced Drainage Effects on Long Uniform Structures

By Robert Pope

Bell Telephone Laboratories, New York, N. Y.

WHEN forced drainage is applied to an underground metallic structure to provide cathodic protection, the greatest effects on the structure and earth potentials occur in the vicinity of the drainage point and anode. These effects taper off as the distance from the drainage point increases and even in the relatively simple case of a long, uniform structure, the manner in which these effects taper off or attenuate is quite complex. (1) (2) However, by making a few justifiable assumptions, relatively simple equations are developed which provide sufficiently accurate results in most practical cases. Furthermore, the simple equations bring out more clearly the relative importance of the various factors involved than do the more rigorous equations. The approximate equations have been used with fair success in predicting the effects of drainage on underground telephone cables in conduit and on buried coated cables. They should apply quite accurately to coated pipes, and there are examples of reasonably good application on some bare pipes. (3)

The soil and structure characteristics which enter into the equations will be discussed, and the units used established.

**Soil Resistivity ( $\rho$ )** in meter-ohms is the resistance of the soil in ohms between opposite faces of a one-meter cube. One meter-ohm equals 100 ohm-centimeters, a unit frequently used. The meter-ohm appears to be a handier unit for engineers since it results in smaller numbers and fewer ciphers.

**Longitudinal Resistance of the Structure ( $R_L$ )** in ohms per kilofoot is the longitudinal electrical resistance of the structure including joints.

**Leakage Resistance of the Structure ( $R_L$ )** in kilofoot-ohms is the electrical resistance in ohms between a 1,000-foot segment of the structure and remote earth. It includes the resistance provided by the soil as well as the resistance of any coating or conduit surrounding the structure.

**Characteristic Resistance ( $R_K$ )** in ohms is the electrical resistance between the structure and remote earth looking in one direction only. For example, the resistance looking east on a structure at any point is the resistance to earth which would be measured if the structure did not exist west of this point. On a long uniform structure, the resistance looking east ( $R_E$ ) is the same as the resistance looking west ( $R_W$ ) and



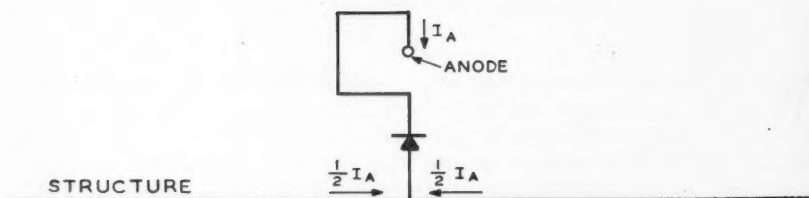


FIG. 1-A DRAINAGE TO NEARBY ANODE

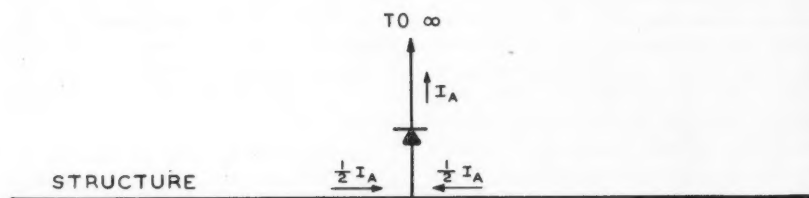


FIG. 1-B DRAINAGE TO VERY REMOTE ANODE

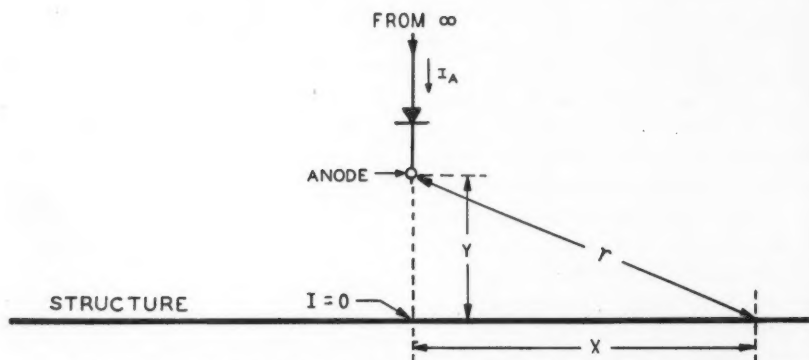


FIG. 1-C CURRENT FROM REMOTE EARTH TO NEARBY ANODE



the actual resistance to earth ( $R_G$ ) is equal to these resistances in parallel or half the characteristic resistance.

$$R_K = 2 R_G \text{ ohms} \quad (1)$$

The characteristic resistance is a function of series resistances representing the longitudinal resistance of segments of the structure shunted by the leakage resistance of these segments. It is related to the longitudinal resistance and leakage resistance as follows:

$$R_K = \sqrt{R_S R_L} \text{ ohms} \quad (2)$$

**Attenuation Constant ( $\alpha$ )** per kilofoot is a characteristic of a structure which determines the rate at which attenuation takes place.

$$\alpha = \sqrt{\frac{R_S}{R_L}} \text{ per kilofoot} \quad (3)$$

or

$$\alpha = \frac{R_S}{R_K} \text{ per kilofoot} \quad (4)$$

In draining a structure to a nearby anode, two effects are superposed. The potential of the structure is depressed (made more negative) and the potential of the earth is raised (made more positive). For purposes of analysis, these effects can be separated by regarding the drainage action as the result of two separate actions. In the first step the drainage current is assumed to be delivered to a very remote anode, and the effect of the anode in raising the potential of the earth in the vicinity of the structure can be considered to be negligible. The only effect of this step then is the lowering of the structure potential. In the second step, the drainage current is assumed to be taken from earth at a very remote point and delivered to earth at the actual anode location. In this

step, with reasonable separation of anode from structure, the change in the structure potential can be considered to be negligible, and the entire effect results in raising the potential of the earth. Figure 1A shows forced drainage applied in the usual manner. Figure 1B shows drainage to a very remote anode, and Figure 1C shows the transfer of current from the remote electrode to the regular anode location.

Figure 2 shows the manner in which these two steps affect the structure and earth potentials. Since both the structure potential and earth potential are affected in the vicinity of the drainage, the change in potential of structure to nearby earth is represented by the value of the ordinate between the two curves.

Where the drainage anode is more than about 500 feet from the structure, it can usually be considered as being sufficiently remote that the effect on the structure potential will follow essentially the laws applying to drainage to a remote electrode.

The effect of drainage is usually measured in terms of volts per ampere, where "volts" refers to the change in structure-to-earth potential at the drainage point ( $V_0$ ), and "ampere" is the value of the drainage current ( $I_A$ ). If the potential electrode is sufficiently remote from both the anode and the structure to be essentially unaffected by them, the change in structure potential at the drainage point, per ampere drained, is the resistance of the structure to earth.

$$R_G = \frac{V_0}{I_A} \text{ ohms} \quad (5)$$



The attenuation of the structure potential caused by the drainage current will follow the attenuation equation as follows:

$$V_x = V_{oe}^{-\alpha x} \text{ volts,} \quad (6)$$

where  $V_x$  is the change in structure-to-earth potential at any point and  $X$  is the distance of this point from the drainage point in kilofeet.

The current from either direction in the structure at the drainage point ( $I_o$ ) is equal to half the drainage current, since the other half of the drainage current comes from the opposite direction.

$$I_o = \frac{1}{2} I_a \text{ amperes} \quad (7)$$

Since the characteristic resistance of a uniform structure does not change from point to point, the current in the structure follows the same attenuation law as the voltage.

$$I_x = I_{oe}^{-\alpha x} \text{ amperes,} \quad (8)$$

in which  $I_x$  is the current in the structure at any point.

The current picked up by the structure from the earth is equal to the decrease in  $I_x$  per unit length, and dividing this value by the circumference of the structure gives the cathodic current density at any point ( $i_x$ ) as follows:

$$i_x = \frac{12 I_{oe}^{-\alpha x}}{\pi d} \text{ milliamperes per square ft.,} \quad (9)$$

or

$$i_x = \frac{12 I_x \alpha}{\pi d} \text{ ma. per square ft.,} \quad (10)$$

where  $d$  is the diameter of the outside of the structure in inches. If  $X=0$ , the cathodic current density at the drainage point ( $i_o$ ) can be determined as follows:

$$i_o = \frac{12 I_o \alpha}{\pi d} \text{ ma. per square ft.} \quad (11)$$

1.

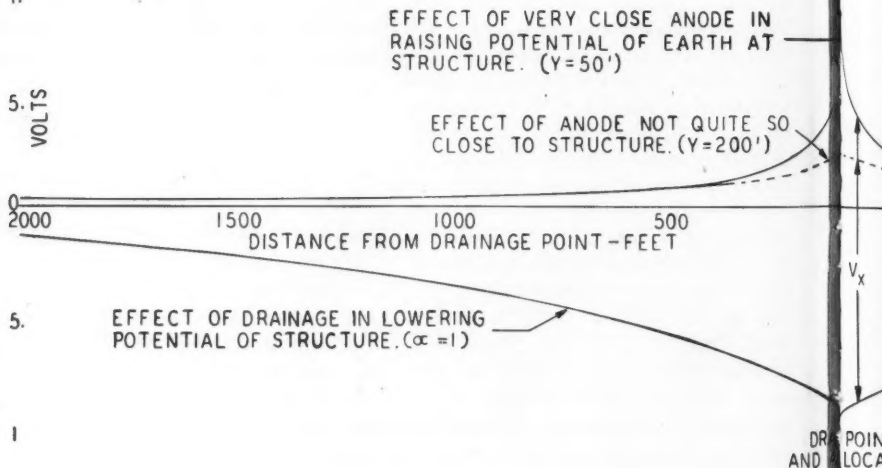


FIG. 2—EFFECT OF DRAINAGE AND ANODE POTENTIAL ON STRUCTURE AND SURROUNDING



Figure 3 shows the application of the approximate equations to obtain curves representing the attenuation of structure potential, current on the structure, and cathodic current density for a 12-inch pipe, where  $R_s=0.004$  ohm per kilofoot and  $R_L=0.1$  kilofoot-ohm. The other characteristics can be computed to be  $R_k=0.02$  ohm,  $R_G=0.01$  ohm and  $\alpha=0.2$  per kilofoot. As indicated on these curves, the effects per ampere at 2500 feet from the drainer are about 0.006 volt to earth, 0.3 ampere on the structure and 0.017 milliamperes per square foot cathodic current density.

By taking the logarithms of both sides of the attenuation equation (as for example  $V_x$ ) we get

$$\alpha x = \log_e \frac{V_0}{V_x} \quad (12)$$

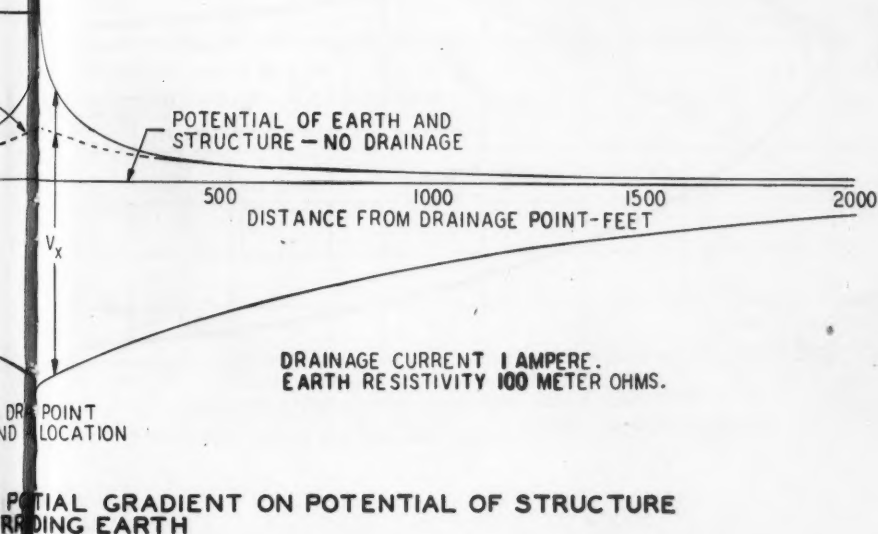
or

$$\alpha x = 2.3 \log \frac{V_0}{V_x} \quad (13)$$

Therefore, these curves appear as straight lines on semi-logarithmic coordinates, and it is necessary to compute only two points, one of which may be the drainage point, and connect them with a straight line to obtain the attenuation curve. The curves shown on Figure 3 are reproduced on semi-log coordinates in Figure 4. The same values are obtained with these curves as will be observed, for example, at the 2,500-foot point.

#### Influence of Attenuation Constant ( $\alpha$ )

Figure 5 is a family of curves illustrating the effect of varying the attenuation constant,  $\alpha$ . In these curves, the effect at the drainage point is taken as unity. The curves





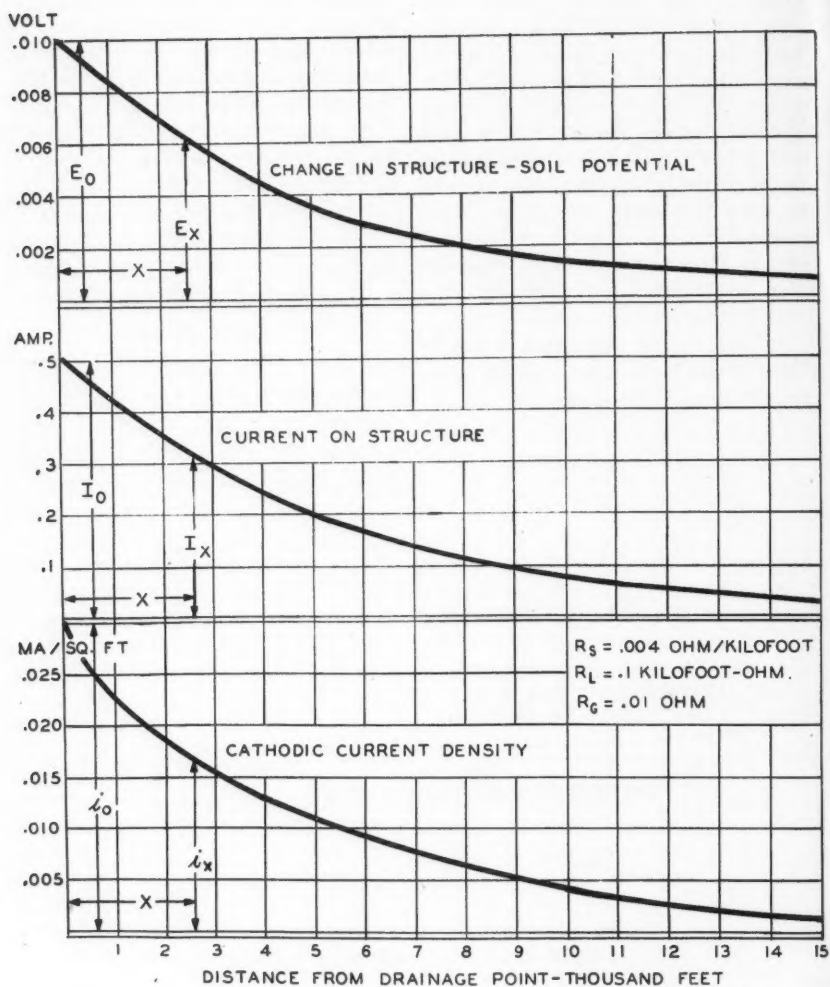


FIG. 3—COMPUTED EFFECT OF DRAINING ONE AMPERE FROM STRUCTURE



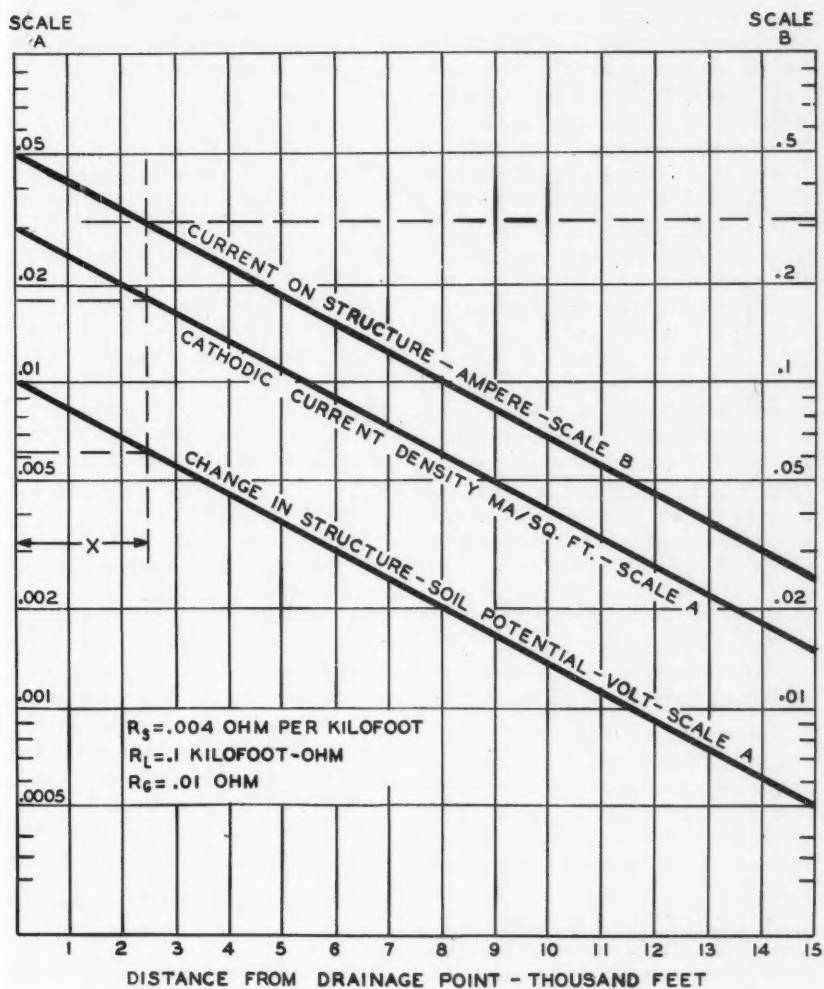


FIG. 4.-COMPUTED EFFECT OF DRAINING ONE AMPERE



can be used to determine the probable effect at any point on a long, uniform structure in the following manner:  $R_s$  can be measured, computed or obtained from tables.  $R_G$  can be measured in the field and  $\alpha$  can be computed from these, using equations (1), (4) and (5).  $R_G$  is the same as  $V_o$  per ampere.  $I_o$  is computed from (7), and  $i_o$  is computed from (11). Thus the conditions at the drainage point are determined.

By taking the attenuation curve corresponding to the computed  $\alpha$ , the proportion of the effect at the drainage point can be obtained for any point along the structure. Using the same 12-inch pipe as in Figures 3 and 4 ( $\alpha=0.2$ ) as an example, the effect at 2,500 feet is a little over 60 percent of the effect at the drainage point. Thus the change in structure-to-earth potential is about 60 percent of 0.01, or 0.006 volt per ampere, the current on the structure is about 60 percent of 0.5, or 0.3 ampere and the cathodic current density is about 60 percent of 0.03, or 0.018 milliampere per square foot.

### Effect of Improvements in Coating

The equations discussed above can be used to illustrate the effect of coating on a structure. In this case, however, the range of values is so wide that it is necessary to use logarithmic scales for both ordinate and abscissa.

Figure 6 shows the structure-to-earth potential attenuation for a 12-inch pipe with various values of leakage resistance. Assuming a one-millivolt change per ampere as being minimum practical effect, the curves can be interpreted as follows:

With 0.01 kilofoot-ohm leakage re-

sistance, corresponding to a bare pipe in sea water (1.4 meter-ohms), the change in potential becomes negligible at less than 2,000 feet. With 10 times this leakage resistance, or 0.1 kilofoot-ohm corresponding to a bare pipe in very low resistivity soil ( $\rho=14$  meter-ohms), the change in potential becomes negligible at about 11,000 feet. With one kilofoot ohm, or bare pipe in normal soil (140 meter-ohms), the change in potential does not become negligible until beyond 50,000 feet. A leakage resistance of 10 kilofoot-ohms represents a bare pipe in high-resistivity soil (1,400 meter-ohms) or a pipe with a leaky coating, and a leakage resistance of 100 kilofoot-ohms can be obtained only with a very good coating. In these cases the effect extends great distances, far beyond the limit of practical application of the approximate equations.

Figure 7 shows the cathodic current density attenuation for the same conditions. This shows that with low-leakage resistance, the current density near the drainage point is relatively high, but the effect does not extend very far. With high-leakage resistance, the current density is lower near the drainage point, but the effect extends farther. In this case, a criterion of negligible protection cannot be assumed, since coated pipe generally requires only a small current density for protection as compared with bare pipe.

### Effect of Anode on Earth Potential

The above discussion applies only to the effect of the drainage on the structure potential. An additional effect is obtained due to the anode raising the earth potential. This is



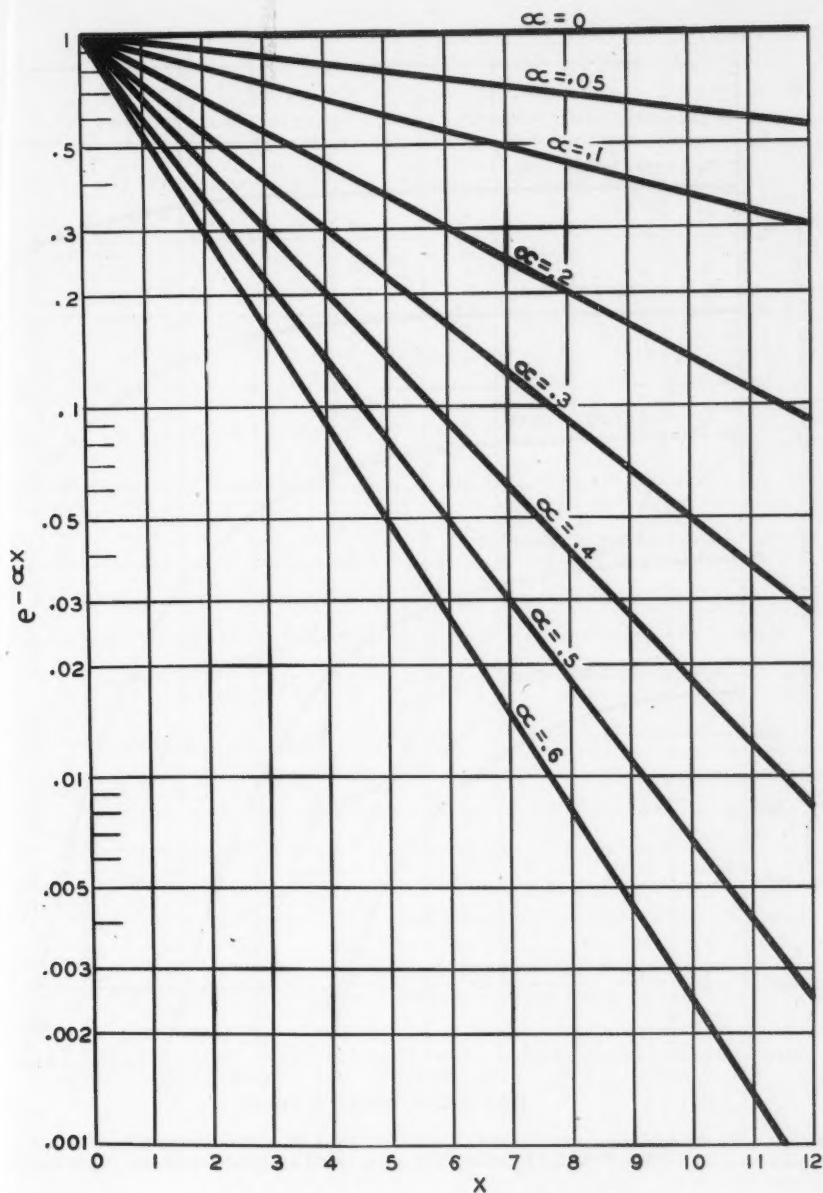


FIG. 5 - VALUES OF  $e^{-\alpha x}$



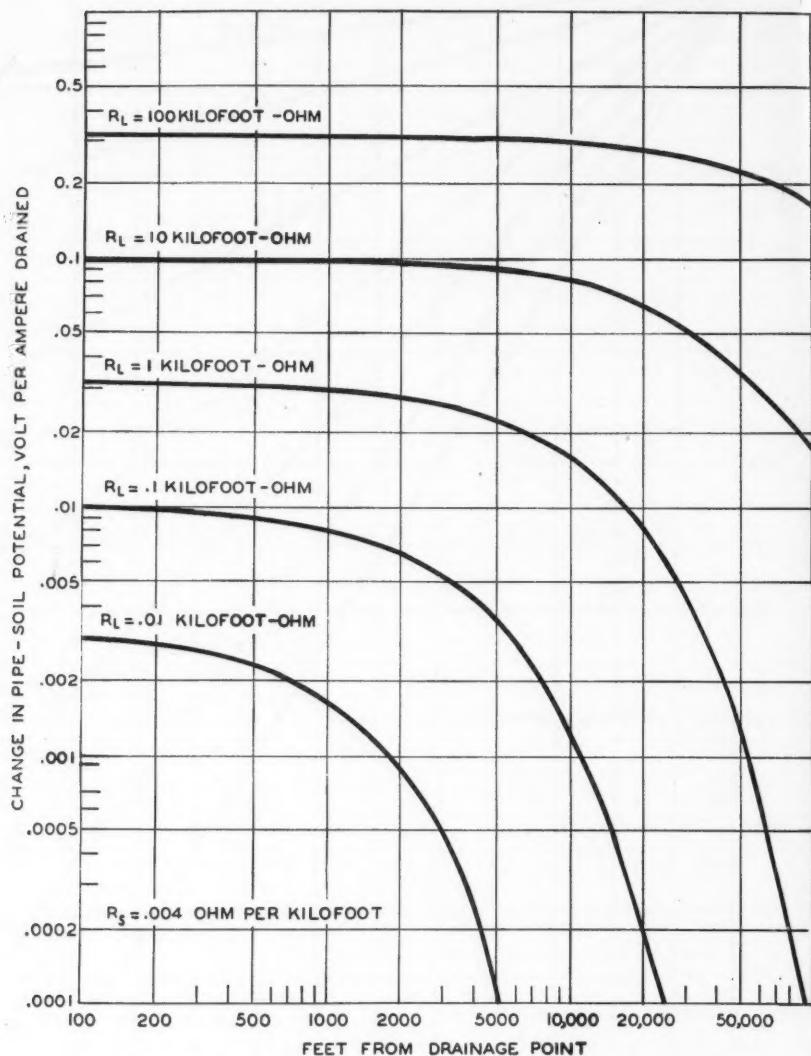


FIG. 6—APPLICATION OF SIMPLIFIED EQUATION TO SHOW EFFECT OF DRAINING ONE AMPERE FROM 12" PIPE LINE WITH VARIOUS LEAKAGE RESISTANCES



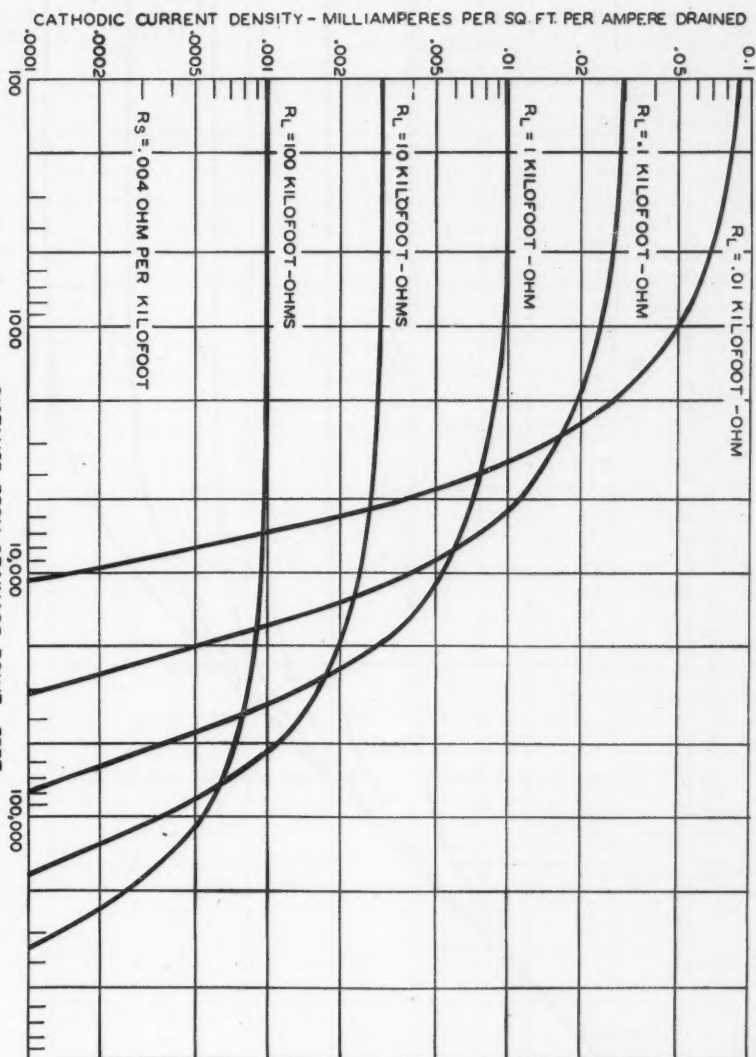


FIG. 7-APPLICATION OF SIMPLIFIED EQUATION TO SHOW EFFECT OF LEAKAGE RESISTANCE ON CATHODIC CURRENT DENSITY-12" PIPE



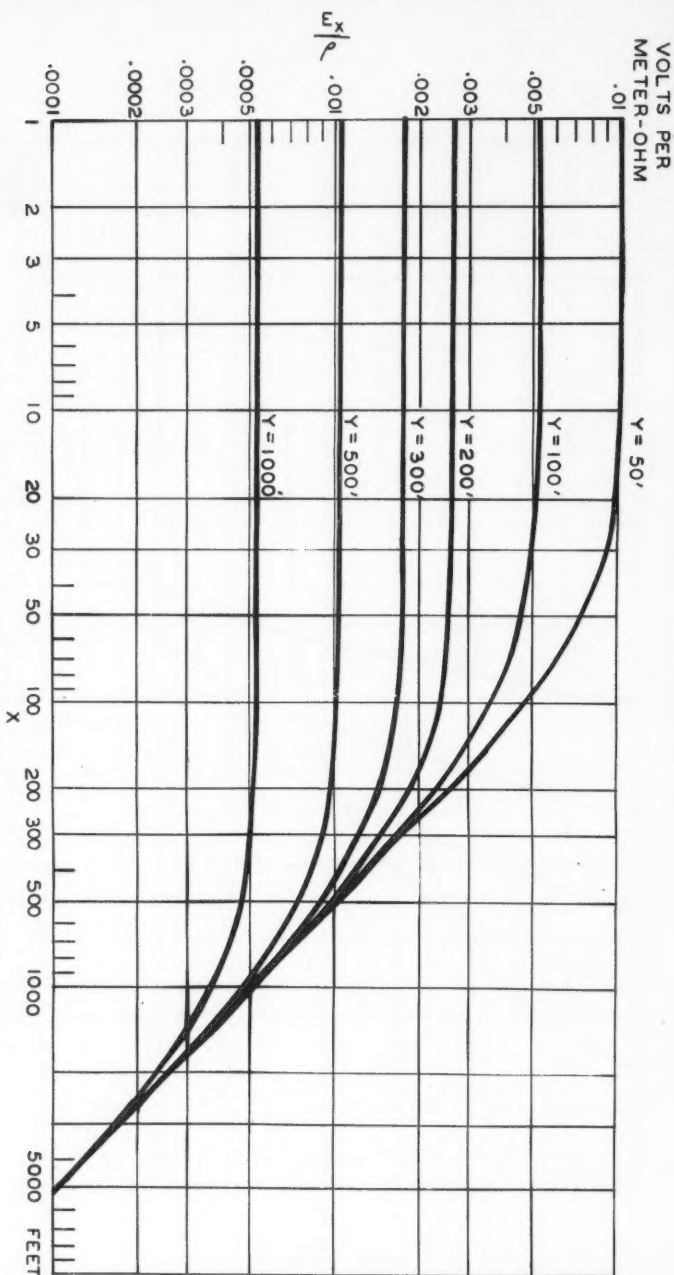


FIG. 8—APPLICATION OF SIMPLIFIED EQUATION TO SHOW EFFECT OF ANODE ON EARTH POTENTIAL



called the anode potential gradient in the earth, and can be determined for the case of a single vertical rod by the following equation:

$$E_r = \frac{1.64 I_A \rho}{\pi L} \log_e \left( \frac{L + \sqrt{L^2 + r^2}}{r} \right) \text{ volts,} \quad (14)$$

where  $E_r$  is the rise in earth potential at any point caused by the current  $I_A$  being delivered to the earth by the anode,  $L$  is the length of the rod below the surface of the ground in feet and  $r$  is the distance from the rod in feet. When  $r$  is more than about  $10 L$ , the equation becomes approximately

$$E_r = \frac{0.522 I_A \rho}{r} \text{ volts} \quad (15)$$

If a bare metallic structure traverses the anode potential gradient, the gradient will be distorted due to the high electrical conductivity of the structure compared with that of the earth. The anode current tends to concentrate on the structure in the vicinity of the anode and this effect will become more pronounced the closer the anode is to the structure. It will also be more pronounced in high resistivity soil than in low resistivity soil.

The current picked up by the structure will be conducted along it, away from the anode location, and this current will create a potential gradient in the structure. If the anode is more than 500 feet from the structure in soil of average resistivity or less (say under 200 meter-ohms) this gradient will be small compared with that caused by drainage current of the same magnitude, and can be considered as negligible

in practical cases. For coated structures this gradient will be even smaller, since less of the anode current will be picked up by the structure. The potential created in the earth, however, may be substantial, particularly in the vicinity of the anode, and should be taken into account. An engineering approximation of this can be obtained in most cases by considering the potential gradient as being undistorted by the presence of the structure. In this way, the earth potential can be obtained for any point along the structure by computing the distance  $r$  (Figure 1) and applying equation (15).

Figure 8 gives values of  $\frac{E_r}{I_A \rho}$  in volts per meter-ohm per ampere for various values of  $x$  and  $y$ . Application of these values will reveal that in extreme cases the effect of the anode gradient may be considerably greater than the effect of the drainage. In such cases where the anode is not located opposite the drainage point, the greatest effect on the potential of the structure to nearby earth will be obtained opposite the anode rather than at the drainage point.

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## Cathodic Protection

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**B**ASICALLY a cathodic protection unit consists of a source of direct current, the negative terminal of which is connected to the pipeline to be protected, and the positive terminal connected to the ground some distance from the pipeline. The ground connection is usually made by means of buried junk pipe or other expendable material, usually referred to as the ground bed. In operation, current flows in the conventional sense from the positive generator terminal to the ground bed, thence through the ground to the pipeline and from there to the negative terminal of the generator. By this means corrosion of the pipeline is reduced, while corrosion of the ground bed is increased. Corrosion is transferred from the structure to be protected to a structure which can be replaced at relatively small cost.

All cathodic protection systems follow this general plan although in details they may differ widely. One line may have a coating which will make it possible to protect several miles of pipe with one unit; another line may require several units to protect the same length of line; and in some cases a line may require a system consisting of a ground bed

distributed along the line and fed at frequent intervals. The corrosion engineer must study each protection job individually and decide which arrangement of the basic elements is the best suited for that particular project.

In the following, an attempt has been made to explain the theory as to how cathodic protection stops corrosion and to review some of the basic laws governing the flow of current in the networks encountered in its application.

One of the principal characteristics of corrosion on a pipeline is that it almost always occurs in small spots or patches while there is little evidence of attack on the surrounding surfaces. It can be shown by electrical measurements that an electric current flows from the pipe to the soil through the corroding spots and from the soil back to the pipe through the non-corroding areas. The areas which discharge current or which corrode are known as anodes, and those which collect current are known as cathodes. One of the most common forms of corrosion encountered in pipeline maintenance is that caused by differential aeration. In this form, part of the surface area has a relatively plentiful supply of oxygen, which reacts with the iron at the surface to form an iron-oxide film in intimate contact

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with the underlying steel. This film serves as a protective coating for those areas, preventing moisture in the ground from coming in contact with the steel. If this oxide film could be formed and maintained evenly and completely over the entire surface of the pipe, it would serve about the same purpose as a nickel plating. However, in practice there are always certain spots or areas which are more or less shielded from oxygen. A root pressing against the pipe will retard the diffusion of oxygen to the underlying steel. Areas having a deficiency of oxygen will become anodes and will corrode, and those with a more plentiful supply will become cathodes.

The cathodes present an oxide surface to the soil, hence they are, in effect, oxide electrodes. The anodes, where there is not enough oxygen to maintain an oxide film are, in effect, steel electrodes. The two are unavoidably bonded together by the metal in the pipe, which completes the closed circuit through which current flows i.e., from pipe-to-soil through the anodes, back to the pipe through the cathodes, and from the cathodic areas to the anodic areas along the pipe.

At the anodic areas current flowing from pipe-to-soil carries iron particles with it which move out from the anode surface until they encounter oxygen, with which they combine to form iron oxide. This action gives rise to the familiar "shell" of corrosion products so often found covering a pit. The shell is formed too far from the corroding surface to stifle corrosion; instead it further retards the diffusion of oxygen up to the anode, thereby aggravating the situation. Therefore, this type of

corrosion when once started, if left alone, will continue until the pipe is penetrated.

It has been found that if current is prevented from flowing from pipe-to-soil at all points, corrosion will stop. This is what cathodic protection does. We have a section of pipeline with innumerable small local action, short-circuited cells, acting to circulate current between adjacent areas on the surface. If we now superimpose another current from an external source so that it flows from soil-to-pipe at all points, it will buck the galvanic current leaving the anodes and increase that already flowing toward the cathodes. There is some value of externally applied current which will buck the anode current to zero and stop corrosion at those points.

Once this condition has been achieved and the iron particles stop leaving the anodic areas, there is nothing to prevent oxygen from eventually diffusing up to the surfaces which were originally anodic, and there forming an oxide film as exists on the cathodic areas. Thus, the effect of cathodic protection is not only to stop corrosion but also to reduce the tendency for corrosion to take place. For this reason it is often possible, after a cathodic protection system has been in service for some time, to reduce the current from the external source. That is, less current is required to prevent corrosion from starting than is required to stop it once it has been allowed to reach its normal rate.

If the applied current is increased materially above that required barely to stop corrosion, the normal potential between the pipe and soil changes; that is the soil becomes



more positive with respect to the pipe. In other words, a voltage is developed across the junction between the pipe and soil in such a direction as to oppose the applied current. This is called polarization and is much the same phenomena that occurs when a storage battery is charged.

The problem of how to determine when the externally applied current is sufficient to stop corrosion is one of the most difficult questions in the whole subject. The designer of a cathodic protection system should know ahead of time what current is required at certain points along the line to enable him to select the proper equipment. One of the most commonly used methods is by means of so-called pipe-to-soil potential measurements.

Before discussing how these measurements are used, it is best to explain what they are. To begin with, the soil contains a solution of water and whatever soluble substances happen to be present, the nature of which determines the corrosivity of the soil. From a corrosion standpoint, the soil may be considered a solution of electrolyte. When we make a pipe-to-soil potential measurement, it is necessary to contact the soil with some kind of electrode and to connect the voltmeter between that reference electrode and the pipe. The voltage measurement so obtained is the voltage of a galvanic cell composed of the pipe as one electrode and the reference electrode as the other, both immersed in the moist earth. It is similar to the voltage between the two terminals of the conventional dry cell battery, in which one electrode is zinc and the other is carbon. The total

voltage observed across the terminals is the algebraic sum of the voltage between the zinc and solution and the voltage between the carbon and solution. We cannot measure each individually; we can only measure the sum of the two. The same thing applies to a voltage measurement between a pipe and reference electrode, and obviously the voltage observed is affected not only by the conditions at the surface of the pipe, but also by the nature of the reference electrode used. If we use a copper rod as reference, one value of voltage is obtained; if we use a rusty steel rod, another value is obtained; if we brighten the same steel rod, the voltage will again change. In order for the measurements to tell us anything about conditions at the pipe surface, it is necessary to use a reference electrode which always contributes substantially the same amount of voltage to the total voltage measured, regardless of where it is placed in the earth. Several such electrodes have been devised, all embodying the same principle. The copper-copper sulphate electrode is the one most commonly used in the field. A copper electrode is surrounded by a saturated solution of copper sulphate in a porous container. In use the earth is contacted by the sulphate solution through the porous container; the solution also contacts the copper electrode to which the voltmeter is connected. With this arrangement, the copper is always in contact with the same solution, and the voltage existing across the metal-solution junction remains constant enough for practical purposes. We do not know what that voltage is, nor is it necessary that we should know. All we



need to know is that it is constant. Throughout the remainder of this paper wherever the term "pipe-to-soil potential" is used, it will be understood that the voltage referred to includes the constant voltage contributed by the copper sulphate electrode, unless otherwise noted.

To get back to the use of pipe-to-soil potential measurements to determine when a pipe is completely protected, let us imagine ourselves in the ground close to the pipe and free to move about and make measurements without disturbing the earth. If we find a corroding spot and place the reference electrode so that it contacts the soil close to that spot, the electrode would be found to be possibly 0.8 volts positive to the pipe. It is convenient to imagine that there is a pump at the surface of the anodic spot pumping current out of the pipe into the surrounding earth. The voltmeter terminal connected to the pipe is connected to the suction side of the pump and the other terminal, connected to the electrode, is connected to the discharge side. Now if we move the electrode along the pipe away from the corroding spot until it lies close to an area where no corrosion is occurring, it will be found to be less positive to the pipe, possibly 0.3 volt. As before, a pump may be imagined at the cathode surface but in this case it is pumping current from the earth to the pipe. The electrode is now located on the suction side of the pump, hence its potential will be lower or more negative than it was when it was placed near the corroding spot. In this illustration, two pumps were assumed to be acting in series with each other, both in the direction of the current flow.

Actually they may be opposed to each other, with one having a higher discharge pressure than the other; or there may be only one. In any case, the same conclusion is reached; that is, the earth potential relative to the pipe is more positive adjacent to a corroding spot than it is near a non-corroding spot.

Now if the electrode is moved away from the pipe, its potential will be influenced by both the anodic and cathodic areas and so will assume a potential somewhere between the 0.8 and 0.3 volt used as illustrative values above; a potential which is an average of the effect of all the anodes and cathodes on the pipe in that immediate vicinity. This is the way pipe-to-soil potential measurements are customarily made; with the electrode some distance from the pipe, usually on the surface of the ground over the pipe.

If a direct current generator is now connected with its negative terminal to the pipe and its positive terminal to the ground, the potential of the latter is forced to move more positive with respect to the pipe. When the potential of the soil around the pipe is raised to a value equal to or greater than the discharge pressure of the anodic "pumps", the discharge of current from those areas stops and consequently corrosion also stops.

The pipe-to-soil potential now includes a portion of the generator voltage equal to the resistance between a cylindrical equipotential surface around the pipe, contacted by the reference electrode and the pipe, multiplied by the generator current.

It has been found in practice that when the soil potential has been forced to a value slightly greater than



0.8 volt positive to the pipe, the frequency of leaks drops off sharply and in most cases drops to zero. Hence the rule of thumb which states that when the pipe-to-soil potential is made greater than 0.8 volt, complete protection has been achieved.

It is possible that in many cases, raising this voltage to 0.8 results in over protection and a consequent extra expense for power and equipment.

Another method frequently employed is to apply enough current to change the pipe-to-soil potential by 0.3 volt. That is, if the normal pipe-to-soil potential was 0.4 volt and the application of cathodic current raised it to 0.7 volt, it is assumed that satisfactory corrosion control has been achieved.

Probably the most exact method is that in which the galvanic voltage between pipe and reference electrode is plotted against the applied current as the latter is increased by steps from zero to several times that required for full protection. From the shape of the curve thus constructed, the value of current at which corrosion was stopped can be determined.

There are arguments both for and against all these methods. Probably each is the correct method in certain localities and has developed as a result of experience in those localities. In cases where protection is applied to a line on which leaks have occurred, the stoppage of leaks after protection is a sure indication that the protection is adequate regardless of which inferential method is used. However, dependence on the leak records alone is not satisfactory from the management's viewpoint, since

it would be necessary to make the expenditure for protection before it was known what the benefits would be. At present the design of cathodic protection systems is mainly dependent on good judgment based on experience in the particular section of the country where protection is desired.

The current required to provide protection to a section of pipeline varies over rather wide limits. In most cases the controlling factor is the coating on the line. Obviously, if a line is well coated, very little applied current will leak through the coating; almost all of the current will enter the pipe through breaks in the coating. Consequently a little current will protect a relatively long section of such a line. On the other hand, if the line is bare, the type of soil which the line traverses becomes the controlling factor. The soil varies radically from point to point along a pipeline, consequently the current requirements also vary. As an illustration, certain tests in three different waters showed that stopping normal corrosion of sanded mild steel coupons in sea water required an average of six milliamperes per square foot; in brackish water, four milliamperes, and in fresh water, 12 milliamperes.

The condition of the pipe surface when the pipe is laid should also have some effect on the current required insofar as it affects the final condition of the surface after normal steady corrosion has been established. If a line is laid without first removing the mill scale, places where the scale has been damaged and the underlying steel is exposed will be anodic and will corrode, tending to prevent corrosion of the areas



where the mill scale is intact. In this case, the distribution of anodic and cathodic areas is predetermined to a large extent when the line is first laid. On the other hand, if the pipe is first run through a cleaning machine and the mill scale removed, its surface is made more or less uniform, and the final arrangement of anodic and cathodic areas will be determined almost entirely by soil conditions met with after the line is laid. The final surface conditions in these two cases will be different; the distribution and extent of the anodic areas will be different; and probably the voltage of the local action cells will be different, resulting in different values of current required for complete protection.

Considering the various factors which control current requirements, it appears that the most practical method of predetermining those requirements is by actual field tests with temporary ground beds and portable generating equipment. Usually a satisfactory temporary ground bed can be made by installing a number of  $\frac{3}{4}$  or 1-inch pipes about six feet long in hand-drilled holes, with the spacing between holes about 20 feet. Back filling with soil mixed with salt water helps reduce the resistance between the rods and earth. The number of rods required will depend on the soil resistance and on the available voltage of the generating equipment. The rods are connected in parallel to the positive terminal of the generator; the negative terminal is, of course, connected to the pipeline.

In making these tests, it is customary to measure the normal pipe-to-soil potential at various points throughout the section where pro-

tection is desired before the test current is applied. Then the test current is adjusted to some arbitrary value and the pipe-to-soil potentials at the same points as before are remeasured. From the data thus obtained and past experience, the engineer can make a reasonably accurate estimate of the protection obtainable from a cathodic unit at that location with a current output equal to that used in the test.

In general, cathodic units should be located along a pipeline at points where leaks have occurred, or if there have been no leaks, at points where trouble is anticipated, judging from soil surveys or from experience with other pipelines in that vicinity. However, more often than not, other factors enter into the selection of the location of a cathodic unit. Availability of a dependable source of electric power, accessibility for maintenance, location of suitable low resistance soil for the ground bed, permission of the land owner to install the unit, and location of other pipelines in the area are the other main factors to be considered. Usually the final location decided upon is a compromise between the theoretical ideal and the practical.

In the application of cathodic protection there are many problems that arise which are often puzzling. Usually a person is in the habit of thinking of current as always flowing from positive to negative, which is natural since most of our experience with electric circuits has to do with that portion where this is true. In any closed circuit, however, if current flows downhill in some parts, it must flow uphill in other parts, in order to return to its starting point.



Where it flows from positive to negative it is giving up energy; where it flows from negative to positive it is receiving energy or, in other words, it is being pumped uphill. This is in accordance with Kirchoff's second law which states in condensed form that, "The total change of potential around any closed circuit is zero." It can be illustrated by plotting the potential changes from point to point around the circuit composed of a dry cell and a conductor connected across its terminals. For convenience, suppose we letter the positive terminal A, the negative terminal B, the solution inside the cell adjacent to the zinc electrode C, and the solution adjacent to the carbon electrode D. Current is flowing through the external conductor from A to B and through the solution of the cell from C to D. Starting at A, the current flows downhill to B through the external conductor; at the junction of the zinc electrode and the solution, energy is added and the current is forced to flow uphill from B to C; between C and D, through the solution, it again flows downhill; and at the junction between solution and carbon it is again forced uphill from D back to A, its starting point.

The galvanic cells on the surface of a pipe may be compared directly with the dry cell. The soil corresponds to the internal portion of the cell between C and D, the anodic areas correspond to the zinc, the cathodic areas to the carbon, and the steel of the pipe corresponds to the external conductor between A and B. In corrosion work, voltage measurements may be made anywhere in the circuit; sometimes with the voltmeter across the downhill portion, sometimes with it across the uphill

portion. In fact, at times it will be across the uphill portion of one circuit and the downhill portion of another. When cathodic protection is applied to a line, a pipe-to-soil potential measurement is made with one terminal connected to the external portion and the other to the internal portion of the galvanic circuits on the pipe surface and, at the same time, both terminals are connected to points in the external circuit of the cathodic unit circuit.

Under these circumstances, it is necessary for the investigator to juggle his thinking in order to picture himself at times outside a battery, inside a battery, or halfway in and halfway out. His correct interpretation of his measurements depends on his knowledge of where he is in the circuit or circuits he is dealing with.

In any cathodic protection installation, we are dealing with a network of a large number of conducting paths, with several voltages acting in the network. In addition to the voltage of the galvanic cells on the surface of the pipe forcing current out of the pipe at some points and back into the pipe at other points, we have the voltage of the cathodic unit forcing current to flow from the ground bed to the pipe through the earth, and the voltage of polarization at the pipe surface mentioned previously which opposes any current being forced onto the pipe. The effect of any one voltage in any part of a network can be measured by removing that voltage without otherwise changing the network and observing the resulting changes that take place at the points in which we are interested. To observe the effect of the cathodic unit alone on the pipe-to-soil potentials, all we have to



do is to connect a voltmeter between the pipe and reference electrode and observe the immediate change in voltage that occurs when the power to the cathodic unit is cut off or on. If we make this measurement at the point on the pipe nearest the ground bed, the change will be a maximum. As we move along the pipe farther and farther away from the unit, the changes will become successively smaller, until a point is reached where they are not discernible, and for all practical purposes are zero. Beyond these points, one in each direction from the unit, substantially no current from the unit reaches the pipe.

The length of pipe receiving current from the unit depends largely on the condition of the coating. Suppose the coating on our line is such that only a one-mile section is receiving current directly from the unit; yet the pipe-to-soil potential measurements show that considerably more than a mile of the line is protected. This is not an unusual case but is in line with what should be expected. The reason is apparent when we consider the third voltage acting in the network, that is, the voltage of polarization at the surface of the pipe near the unit. In order to visualize how this acts, imagine that the one-mile section which receives current from the unit is made of zinc instead of steel and that the cathodic unit does not exist. With this arrangement, current will flow from the zinc section to the steel pipe through the earth, and back along the pipeline, and in so doing will protect cathodically a certain amount of the steel pipe. According to Ohm's law, the current that would

flow would be proportional to the driving voltage and inversely proportional to the resistance of the circuit. Hence, the protective effect on remote parts of the pipe from this source is more pronounced where the circuit, composed of the earth and the pipeline in series, has a low resistance.

Now take out the zinc section of line and make it steel again and turn on the cathodic unit. Polarization of the steel pipe receiving current from the unit, due to that current, makes it look like zinc to more remote parts of the line, and like zinc it will protect a certain amount of the remote pipe. The action of the current from the unit is to maintain it in that anodic state, and at the same time to prevent it from corroding by supplying it with more current than it discharges.

So far, this paper has considered only the effect of cathodic protection on the pipeline to which it is applied. Its effect on other pipelines in the vicinity, not included in the protective scheme, may be injurious and must be considered in any cathodic protection project.

With respect to the cathodic unit, a foreign pipeline lying in the earth in the vicinity of the unit is simply a part of the earth, and as such will serve as one of the many parallel paths to conduct current from the ground bed to the pipe under protection. At points where it picks up current, corrosion will be reduced and at points where it discharges current, corrosion will be increased. To determine at any given point whether it is collecting or discharging current from a particular cathodic unit, it is only necessary to connect a voltmeter between the pipe



and soil at that point and note the change in pipe-to-soil voltage as the unit is turned on and off, in the same way that the spread of current on the protected line was found. If the soil potential with respect to the foreign line goes more positive when the unit is turned on, some of the current from the unit is flowing onto the pipe at that point. If the soil potential moves in the negative direction, the opposite is true. The cathodic unit affects a foreign line only insofar as it affects the potential difference between the line and the surrounding earth.

A cathodic unit in operation forces the potential of the ground bed to shift in the positive direction and that of the pipeline in the negative direction. Each tries to pull the potential of the earth along with it but since they are pulling in opposite directions, their combined effect on remote points in the earth is zero. However, the potential of the earth relatively close to the unit is distorted. Points close to the ground bed are influenced more by the ground bed than by the pipeline, hence the net effect of the two is an increase in potential. Those close to the pipeline are effected more by the pipe, resulting in a net decrease in potential.

Let us suppose that a foreign line crosses the protected line somewhere well within the field of the cathodic unit, and that we measure the effect of the unit on its pipe-to-soil potential at various points. At a point remote from the protected line but as near as possible to the ground bed, the ground will swing more positive with respect to the pipe when the unit is turned on. As we move the voltmeter toward the protected line,

we eventually find a point where the pipe-to-soil potential is unaffected by the unit. Here the effect of the ground bed and the protected pipeline is exactly equal and opposite, so there is no net discharge or collection of current. Moving still nearer the protected line, the soil potential begins to swing negative and reaches a maximum negative value at the crossing. The protected line also swings negative with respect to the foreign line. The customary procedure for relieving the exposure is to place a metallic bond between the two lines of such a resistance that the unprotected line is forced in the negative direction by the same amount that the soil is forced in that direction. This is usually done by the trial and error method. When the correct resistor is used, there will be no change in the pipe-to-soil potential of the foreign line at the crossing when the cathodic unit is turned on and off. At all other points, the unit will cause the earth's potential to move in the positive direction with respect to the foreign line. After the correct bond is installed, there will be a voltage difference between the two lines, with the protected line being negative to the foreign line. This is as it should be, since the ground bed is positive to the foreign line, and the combined effect of the ground bed and protected line on the unprotected line at the crossing is zero.

Ordinarily there is a galvanic voltage between any two pipelines even when there is no outside influence such as a cathodic unit. A bond between the two closes the circuit of the galvanic cell to permit a current to flow, to the detriment of one, just as short-circuiting a dry cell battery



results in deterioration of the zinc. For this reason, cross bonds should be avoided except when necessary due to some outside influence. In general, when a cross bond is required, it should not have a lower resistance than necessary to accomplish its purpose. Often the effect of the protected line on the pipe-to-soil potential of the other line can be reduced by means of an extra-heavy coating on the former for about 25 feet each side of the crossing. The exposure being less, not as much current drainage is required and a higher resistance bond can be used.

When the foreign line lies outside the direct field of the cathodic unit but inside the field of the long line currents due to polarization established and maintained by the unit, the procedure in adjusting a cross bond is the same, except that when the unit is turned on or off, the resulting changes in pipe-to-soil potentials occur slowly.

Most of the electrical measurements in cathodic protection work are voltage measurements. The selection of an instrument for a particular voltage measurement depends on the characteristics of the circuit to which it is connected. Pipe-to-soil potentials using the copper-sulphate electrode should be measured with a very high-resistant or a

potentiometer type instrument which requires little or no current from the measured circuit. If any appreciable current is allowed to flow through the electrode, it will polarize to some extent and its voltage will change. Other voltage measurements in which the copper-sulphate electrode is not employed may be made with an indicating instrument such as the Weston Model 1 voltmeter. This instrument is particularly useful in measuring the voltage difference between two points on a pipe to determine the current flowing in the line and the changes in pipe-to-soil potentials due to turning a cathodic unit on and off. In the latter case, the potential of the reference electrode cancels out, so any convenient electrode, such as a steel bar, may be used to contact the earth. The correction necessary to compensate for the error introduced by resistance of the voltmeter circuit, external to the instrument, is:

$$\text{Open circuit voltage} = \frac{\text{voltage read} \times \text{total circuit resistance}}{\text{instrument resistance}}$$

This paper is rather brief for a subject of this nature. Some points have been touched on very lightly and others omitted entirely, but it is hoped that it will at least provide a fair picture of the fundamental factors involved.



## Chemical Corrosion Resistance of Lead

**L** EAD may be economically employed with many of the chemicals used in the process industries. The following partial list of such chemicals, with brief comments on the reactions they may be expected to have with lead, is intended as a general guide in the selection of materials of plant construction. Because of the broad range of chemicals and the wide variation of operating conditions existing in modern industry, a more complete and more specific list would be impractical.

**Acetic Acid**—Moderately corrosive to lead but corrosion is greatly accelerated by high velocities and temperatures and the presence of oxygen. Lead is used for storage of acetic anhydride and glacial acetic acid.

**Acetone**—Lead may be used satisfactorily.

**Acetylene**—Little effect on lead.

**Alcohol, Ethyl**—No effect on lead.

**Alcohol, Methyl**—No effect on lead.

**Aluminum Sulphate or Alum**—Lead may be used satisfactorily.

**Ammonia**—Lead is unaffected by the dry gas, and by liquid unless sodium or potassium are dissolved in it.

**Ammonium Azide**—No effect on lead.

**Ammonium Chloride**—Lead may be used at ordinary temperatures with concentrations up to 10 percent.

**Ammonium Hydroxide**—Lead satisfactory with liquid or gas at practically all temperatures and concentrations.

**Ammonium Phosphate** — Lead may be used satisfactorily.

**Ammonium Sulphate**—Lead may be used satisfactorily.

**Antimony Chloride**—Lead is somewhat corroded, but is used with comparative economy for chlorinating the tri-chloride to the pentachloride.

**Benzyl Chloride**—Lead may be used satisfactorily.

**Boric Acid**—Lead may be used satisfactorily.

**Brine**—(see Sodium Chloride).

**Bromine**—Lead may be used when cold and acid free.

**Calcium Carbonate**—Found in natural waters and forms a good protective coating on lead. Added to water to reduce plumbo-solvency.

**Calcium Hydroxide**—Presence in green cement corrodes lead in presence of moisture and oxygen. However, added to soft waters reduces plumbo solvency.

**Carbonates, Soluble**—Act as a protection to lead in natural waters unless present in excess, when it increases solubility. Lead is used in acid carbonate systems for generating  $\text{CO}_2$ .

**Chlorinated Hydrocarbons** — Ac-



tion on lead varies from slight to severe depending upon breakdown to HCl and presence of organic acids.

**Chlorination Processes**—Lead is slowly corroded at temperatures usually used, but has satisfactory life and greater economy compared with other common metals.

**Chlorine**—Dry does not affect lead, and lead may be used with moist chlorine up to about 110° C. with slight corrosion. Amounts of chlorine used in water treatment do not affect lead.

**Chromic Acid**—Since chromates form a good protective coating on lead, lead may be used with fairly high concentrations of this acid. Antimonial lead is widely used in electroplating.

**Cinders**—Lead embedded in cinders should be protected.

**Coal Tar**—Lead used in refining and recovery of many by-products.

**Concrete, Cement or Mortar**—When green, free lime present attacks lead. Aging to carbonate lime or applying asphalt coating on lead recommended to prevent such corrosion.

**Copper Sulphate**—Lead is used for anodes and tank linings in electroplating.

**Ether**—Little or no effect on lead. Lead used in its manufacture.

**Ferrous Sulphate**—Lead used for tank linings and coils in production and use.

**Formaldehyde (Formic Acid)**—Action on lead similar to that of acetic acid.

**Hydrochloric Acid**—Use of lead is not generally recommended, but it has been used with some corrosion

in concentrations up to 30 percent at normal temperatures and 20 percent at 100° C. Antimonial lead shows better resistance than ordinary lead.

**Hydrofluoric Acid**—Lead is commonly used and has fair resistance to dilute acid.

**Hydrogen Chloride (Anhydrous Hydrochloric Acid)**—Little effect on lead.

**Hydrogen Peroxide**—Not likely alone to affect lead, but accelerates acid corrosion.

**Koch Acid Reduction Mass**—Lead may be used satisfactorily.

**Magnesium Chloride**—Corrodes lead as it does other metals.

**Malachite Green Mother Liquor**—No appreciable effect on lead at 80° C.

**Mixed Acids**—Mixtures of sulphuric and nitric acids can be used with lead at ordinary temperatures if water present is less than 30 percent.

**Naphthalene**—No effect on lead.

**Nitration Mixture of H-Acid**—Lead is used with rather high corrosion.

**Nitric Acid**—Lead is not generally recommended with this acid, but is used with little corrosion when concentrations are above 80 percent at normal temperature.

**Nitro-Benzol and Nitro-Chlor-Benzol**—Corrosive to lead.

**Nitrocellulose**—Lead widely used as in all rayon manufacturing processes.

**Nitroglycerine**—Lead used to handle spent acid.

**Nitrosyl-Sulphuric Acid**—Action on lead is least at specific gravity of



about 1.5 to 1.6. Close control thus minimizes corrosion.

**Organic Acids**—In general, accelerate the corrosion of lead, but their presence in solutions does not always preclude the use of lead.

**Oxygen**—Dry gas merely tarnishes lead. In presence of water initial attack is usually followed by formation of protective coating formed by salts such as carbonates, sulphates and silicates in the water. In absence of these salts, deaeration may be employed to remove oxygen because of its action on all metals.

**Oxy-L Acid**—Lead is corroded to some extent but is about the only economical metal that can be used with satisfaction.

**Phenol**—Lead may be used satisfactorily.

**Phosphoric Acid**—Lead may be used with concentrations up to 80 percent below 200° C. Impure acid has even less effect on lead and can be used up to 85 percent concentration.

**Photographic Solutions**—Lead is satisfactory generally.

**Potassium Permanganate** — Attacks lead.

**Pyridene**—Does not affect lead.

**Silicates**—Form protective coatings on lead, and thus can be recommended for treating natural waters if necessary.

**Sodium Bisulphate**—Can be handled in lead when highly concentrated.

**Sodium Carbonate**—Dilute solutions do not affect lead; in natural waters forms protective coating on lead.

**Sodium Chloride**—Lead satisfactory for dilute solutions at ordinary

temperatures. Sea water and brine are commonly handled in lead or antimonial lead.

**Sodium Hydrosulphite** — Lead may be used satisfactorily.

**Sodium Hydroxide**—Lead can be used with concentrations up to 25 percent and temperatures of 80° C.

**Sodium Hyposulphite**—Lead can be used satisfactorily.

**Sodium Hypochlorite**—Attacks lead.

**Sodium Sulphate**—Lead can be used satisfactorily with solutions up to 10 percent concentration boiling.

**Sodium Sulphide**—Lead can be used satisfactorily with these solutions at temperatures up to 100° C.

**Sodium Sulphite**—Lead can be used with solutions up to 20 percent concentration at 25° C.

**Sulphur Chloride**—Has little effect on lead.

**Sulphur Dioxide**—Has little effect on lead when dry and can be used moist up to about 200° C.

**Sulphuric Acid**—Lead is the standard material for handling this acid. It can be used with concentrations up to 96 per cent at room temperature and 85 percent up to 220° C. It is sometimes used satisfactorily even up to 250° C. Hard lead, i.e., lead alloyed with small proportions of antimony, has equal or slightly better resistance to sulphuric acid.

**Sulphurous Acid**—Lead is satisfactory up to about 220° C.

**Tannic Acid**—Somewhat similar to acetic acid.

**Tartaric Acid**—Somewhat similar to acetic acid.



**Thionyl Chloride**—Lead is used satisfactorily up to 220° C. and sometimes higher.

**Titanium Sulphate**—Solutions can be handled satisfactorily in lead.

**Victoria Green Mother Liquid**—Lead may be used satisfactorily up to 80° C.

**Water, Distilled**—Dissolves lead very slowly in proportion to amount of dissolved oxygen.

**Water, Natural**—Usually no effect on lead because of protective coating formed from dissolved salts. Very soft waters or those of peaty origin may dissolve lead slightly, as they do other metals, and such ac-

tion can be prevented by treatment of the waters with lime or sodium silicate.

**Wood**—Most wood has little or no corrosive effect on lead. A few instances of corrosion by wood containing organic acids, such as green oak, have been reported. Wood to be lined with lead should be inspected for presence of borers.

**Zinc Chloride**—Lead can be used satisfactorily.

EDITOR'S NOTE: This information has been compiled by the Lead Industries Association, 420 Lexington Avenue, New York, N. Y. It is reprinted here with their special permission.





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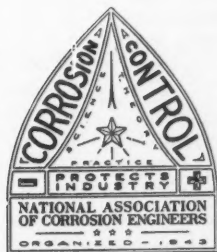
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## Corrosion News Section

### PERSONALS

**W. J. O'Brien**, vice president and director, Glidden Company, Cleveland, Ohio, has been named chairman of a committee of Glidden Executives in charge of manufacturing, research and development. Committee members include three other vice presidents: R. W. Levenhagen, Paul E. Sprague, and Dwight P. Joyce.

**William Rodgers** has been appointed assistant chief metallurgist, Republic Steel Corp., Cleveland. He was superintendent of the corporation's 98-inch hot strip mill in Cleveland. Raymont C. Gintert has been appointed superintendent of the Cleveland hot and cold strip mills for Republic. William E. Boger has been appointed assistant superintendent.

**Earl W. Mahoney**, former metallurgist of the Brier Hill plant, Youngstown Sheet and Tube Co., has moved to the company's main offices in Youngstown. He is associated with Karl Fethers, special metallurgical engineer, and works

out of the office of J. L. Mauthe, vice president in charge of operations.

**Dr. R. B. Mears**, formerly with the Research Department of the Aluminum Company of America, is now Electrochemist for the United States Steel Corporation of Delaware, Research Laboratory, Kearny, New Jersey.

**E. A. Tice**, formerly with the Research Department of the Bethlehem Steel Corporation, is now with the International Nickel Company, New York, where he is working on corrosion problems with F. L. LaQue.

**Emil G. Holmberg** has been appointed consulting metallurgist for Alloy Steel Products Company, Linden, N. J. Mr. Holmberg, a graduate of the Colorado School of Mines, for a number of years was research metallurgist specializing in corrosion problems at the Belle, W. Va., plant of E. I. du Pont de Nemours & Company, Inc.



## NEW PRODUCTS

**Prufcoat Laboratories, Inc.**, Cambridge, Mass., manufacturers of protective coatings, have recently issued literature describing their products. Prufcoat combines in one material a coating that can be applied to concrete, structural steel, floors, pipes, tanks and machinery. It is said to be applicable both inside and outside and to provide protection against acids, alkalies, oil and water.

For the protection of concrete, masonry and metal structures from corrosion and deterioration, a new type of cold-applied coating, called Bituplastic, has been developed by the Wailes Dove-Hermiston Corporation, Westfield, New Jersey. Rigid laboratory and field tests of the coating over a period of years show that it can be applied where damp surfaces formerly interfered with the effective application of regular protective coatings.

Bituplastic is a black, irreversible dispersion. When dry, it forms a tenacious, waterproof film which does not revert to its original state. In all applications, adequate drying conditions are necessary, but drying time is short.

The new material contains no volatile solvents, eliminating discomfort to workmen and danger of fire or explosion when applications are made in confined spaces. Actually the material is a fire retardant, being practically incombustible. It is also virtually odorless and tasteless.

The new coating can be applied to a very thick film in individual coats either by hand brushing or with standard spray equipment. The

usual application is at a rate of 75 to 100 square feet per gallon per coat. Because of its rapid drying characteristics, two coats can be applied in a continuous operation where surfaces are fairly large and normal atmospheric drying conditions exist.

It is claimed the coating will not flow or sag at any temperature up to 600° F., its disintegration point, nor does it alligator in direct sunlight.

The manufacturer states the new product also is effective as a "vapor seal" over various types of standard insulating materials. Having a high degree of plasticity and strong bonding ability, it is applied directly to the insulating material or used to bond the insulation to the surface to be protected. It can be applied over old vapor seal coatings that have begun to disintegrate, prolonging the life of the underlying insulating material.

In common with other Bitumastic blacks made by the company, Bituplastic provides dependable, long-lasting protection against the corrosive attacks of chemicals, chemical fumes, moisture and temperature changes.

**Corrosion of steam lines** and return condensate piping in industrial plants has been eliminated through the use of an organic chemical treatment proportioned into the steam, according to statements of D. W. Haering & Co.

Pulp paper mills on the West Coast have installed H-O-H Model B Feeders to introduce a solution of



organic glucosates into the steam flow ahead of the drying machines. The proportioning units, being activated by the steam flow through the heater, automatically respond to any variation in steam consumption and guarantee accurate and continuous treatment dosages.

The chemical passivates corrosion through the formation of an inhibitor film on the metal surfaces of the system piping. The absorbed film is of molecular dimension and does not interfere with the transmission of heat through the pipe walls. The solution, dispersed in the vapor, is carried throughout the entire system and is present in the condensate at and after the condensation point, thereby maintaining the inhibitor film intact.

A complete story on this interesting solution to a perplexing problem is to be found in the special edition of the H-O-H Lighthouse just off the press. A copy may be obtained by writing, on your company letterhead, to D. W. Haering & Co., 205 West Wacker Drive, Chicago 6, Illinois.

**Demand for effective water purification systems for industrial purposes** has increased measurably in recent months and probably will continue to rise as industry strives to get into full production, according to Hugh M. Corrough, director of American Locomotive Company's Alco Products Division.

As one of the largest shell and tube heat exchanger manufacturers, American Locomotive Company is currently active in solving evaporation problems in collaboration with the planners of new projects. Production is now high, and Alco anticipates little difficulty in meeting delivery requirements for evaporators. However, like most manufacturers, Alco is hampered by shortages of materials, but, these are not critical enough to interfere markedly with production schedules.

To answer many inquiries regarding Alco Evaporators, American Locomotive Company has just issued an interesting booklet featuring its evaporator "flex-tube" design, which, the company says, is "the only positive acting true thermo-mechanical descaling device for straight tube installation."

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### GENERAL INTEREST

**E. I. du Pont de Nemours & Co.**, of Wilmington, Del., has let a contract to Leonard Construction Company of Chicago, Ill., for a \$500,000 sulphuric acid plant to be built in Richmond, Va.

**Construction will soon** start on the \$10 million chemical plant of Jefferson Chemical Company at Port Neches, Texas. Lummus Company

and E. B. Badger & Sons Co., of Port Arthur, Texas, are the contractors.

**A \$12 million plant** for manufacturing of copper tubing will be erected near Decatur, Ala., by Foster & Creighton of Nashville, Tenn., for the Calumet & Hecla Consolidated Copper Company, Wolverine Tube Division, of Detroit, Mich.



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we pledge continued cooperation in your fight against corrosion and take this opportunity to express our sincere thanks and appreciation for your past patronage.

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**Tom L. Holcombe**, of Dearborn Chemical Company, Shreveport, La., General Chairman of the NACE Conference and Exhibition, has been working hard getting things lined up for the 1947 meeting, which will be held April 7-8-9-10 at the Palmer House in Chicago.

The American Coördinating Committee on Corrosion is undertaking a revision of its confidential directory of technologists actively engaged in studies on corrosion and its prevention. The committee comprises delegates from 17 major technical societies, together with representatives from the principal industrial research institutes and other organizations such as the National Bureau of Standards. Its directory currently lists some 500 investigators in a diversity of specialized fields selected on the basis of questionnaires circulated to the membership of the committee's member societies.

While it is felt that the directory list is relatively complete, there are undoubtedly individuals who were not reached in the previous circulations. Accordingly, the committee now requests all persons actively engaged in corrosion researches who have not been contacted, to write the secretary, Professor Hugh J. McDonald, Illinois Institute of Technology, Technology Center, Chicago 16, Illinois, for further details and application forms for directory listings.



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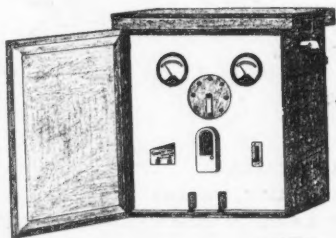
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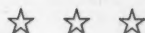


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